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INDUSTRIAL TECHNOLOGY MODERNIZATION PROGRAM

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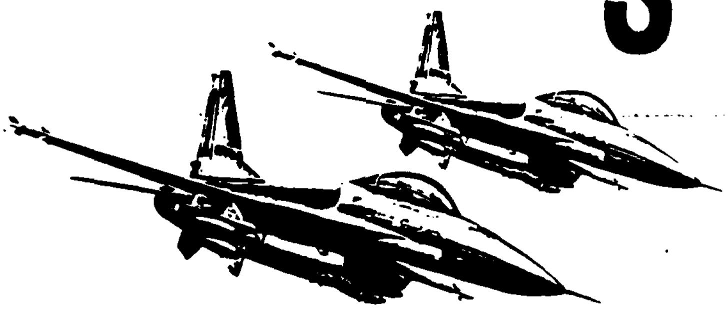

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FINAL TECHNICAL REPORT

CATEGORY 2 PROJECT

COMPUTER AIDED PROCESSING SYSTEM (CAPS)

MARCH 20, 1987

INDUSTRIAL
TECHNOLOGY MODERNIZATION
PROGRAM

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The purpose of this project is to improve manufacturing operations utilizing computer technology.

The Computer Aided Processing System

CAPS will provide manufacturing detailed instructions at a minimal cost and timely manner. The CAPS instruction sheet generator will utilize computer technology to access key information from CAD and the Tracor manufacturing control system in a real time environment, thus minimizing the amount of manual calculation and data entry required to produce a manufacturing package.

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Tracor Aerospace

FINAL TECHNICAL REPORT
CATEGORY 2 PROJECT
COMPUTER AIDED PROCESSING SYSTEM (CAPS)

SUBMITTED TO:
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March 20, 1987

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LIST OF ILLUSTRATIONS

COMPUTER AIDED PROCESSING SYSTEM

1.0 INTRODUCTION

1.1 Project Objective

This Phase III proposal is the result of the completion of Phase II of the Computer Aided Processing System (CAPS) project. The primary objective of this project has been to improve manufacturing operations in the Printed Wiring Board (PWB) Assembly area through the use of computer technology.

The CAPS project addresses five elements of the PWB Assembly process:

* PWB Assembly Instructions
* Auto Component Insertion Programming
* PWB Assembly Testing
* PWB Assembly Repair
* PWB Identification

These elements are integrated into a single computer aided processing system utilizing a central minicomputer to control the functions of each element and to coordinate the use of common data. Communication links are established to facilitate transfer of data to and from other computer based systems.

1.2 Reason for Project

During the Phase I analysis of the cost drivers in Tracor Aerospace Manufacturing Division, the PWB Assembly area was identified as the most labor intensive of the production areas. Virtually all of the products in this division utilize PWB Assemblies in their design. Therefore, productivity improvements in this area would have a significant effect on overall factory productivity.

1.3 Areas Impacted

The scope of the CAPS project is limited, presently, to the areas associated with the assembly, test and repair of PWB Assemblies. Some savings however, may be generated in other manufacturing areas as a part of future projects. Specific areas impacted are listed in Figure 1-1.

1.4 Technologies Utilized

Various types of computer technology were used throughout the CAPS project. The focal point of CAPS is the central minicomputer which is a Digital Equipment Corporation VAX 11/750 with a VMS version 4.3 operation system. The programming language used for the majority of the CAPS software is VAX Pascal version 3.2. Each of the elements of CAPS, as well as the communication network linking them to the VAX computer, utilize various types of computer software and hardware, which are summarized in Figure 1-2.

AREAS IMPACTED BY CAPS

Benefit	Area Affected
I. Instruction Sheet Generator	
A. Reduced Time to Produce Instruction Sheets	
1. New Assembly	Mfg. Engr.
2. Revision to Current Assembly	Mfg. Engr.
B. Increased Efficiency for Input Bill of Labor into TMCS	
1. Reduced Input Time - New Assembly	Document Control
2. Reduced Input Time - MCO	Document Control
C. Increased Efficiency in Manufacturing due to more Information	
1. Prep Setup	Manufacturing
2. Standardized Times and Methods	Manufacturing
D. Increased Efficiency due to Method Analysis	Manufacturing
II. Component Insertion Program Generator	
A. Reduced Time to Produce Insertion Programs	
1. New Assembly	Manufacturing
2. Revision to Current Assembly	Manufacturing
B. Increased Efficiency in Manufacturing due to more Information	
1. Sequencer Setup (parts orientation/location)	Manufacturing
2. VCD Inserter Setup (board orientation)	Manufacturing
3. DIP Inserter Setup (parts and board orientation/location)	Manufacturing
C. Reduced Run Time in Manufacturing due to Calculation of "Shortest Path" for Insertion	Manufacturing
III. Computer Aided Repair	
A. Reduced Time to Locate Defective Parts	Test Tech
B. Reduced Time to Locate Defective Traces	Test Tech
C. Reduced Time to Order Replacement Parts due to more Information	Test Tech
D. Reduced Time to Produce Auto Test Equipment Software due to Information from ECAD Link	Test Engr.
E. Reduced Time to Produce Instruction Sheet Sketches due to Hardcopy Feature	Mfg. Engr.
F. Increase Efficiency in Manufacturing Engineering due to more Information from Board Image on Computer Terminal	Mfg. Engr.
IV. Auto Test Equipment Utilization	
A. Reduced Time to Identify Defective Parts for 8 Board Assemblies	Test Tech
B. Reduced Time to Identify Defective Traces for 8 Board Assemblies	Test Tech
C. Facilitates Defect Analysis	Manufacturing

Figure 1-1

CAPS HARDWARE/SOFTWARE

QTY			
	COMPUTER SYSTEM:		
1	DEC VAX 11/750	CPU with 8 MB Memory	*
2	RA 81	456 MB Hard Disk Storage	*
1	TU 80	Mag Tape Drive	
2	Able Computer Attach	Comm Box (32 ports/box)	**
2	DZ 11	Comm Board (8 ports/brd)	
1	LA 120	Console Terminal	
1	Printronix P 300	Printer	**
3	US Data Password	Modem	
1	VMS version 4.3	Operating System Software	
1	Pascal version 3.2	Programming Language	
1	Ingres version 3.1	Data Base Management Software	**
	CAD COMM LINK:		
1	Model 10	Kaypro Microcomputer	
1	Giltronix #6847	Auto Port Switcher (7 ports)	
1	Giltronix #C4506	Manual Port Switch	
1	US Data Password	Modem	
	MANUFACTURING INSTRUCTIONS	GENERATION:	
3	DEC VT 240	Video Terminal	
1	Printronix P 300	Printer	**
	AUTO COMPONENT INSERTION:		
2	TRS 80 Model II	Microcomputer	**
1	Giltronix #6847	Auto Port Switcher (7 ports)	
1	Remark Datacom	20 MA to RS 232 Converter	
1	US Data Password	Modem	
	COMPUTER AIDED REPAIR:		
1	Seiko GR1104	Color Graphics Video Terminal (Tektronix 4014 compatible)	
	AUTO TEST:		
8	Hewlett-Packard	Custom Auto Test Fixture	
8	Hewlett-Packard	Custom Auto Test Software	

* = Cost partially covered by other projects
** = Cost covered by other projects

Figure 1-2

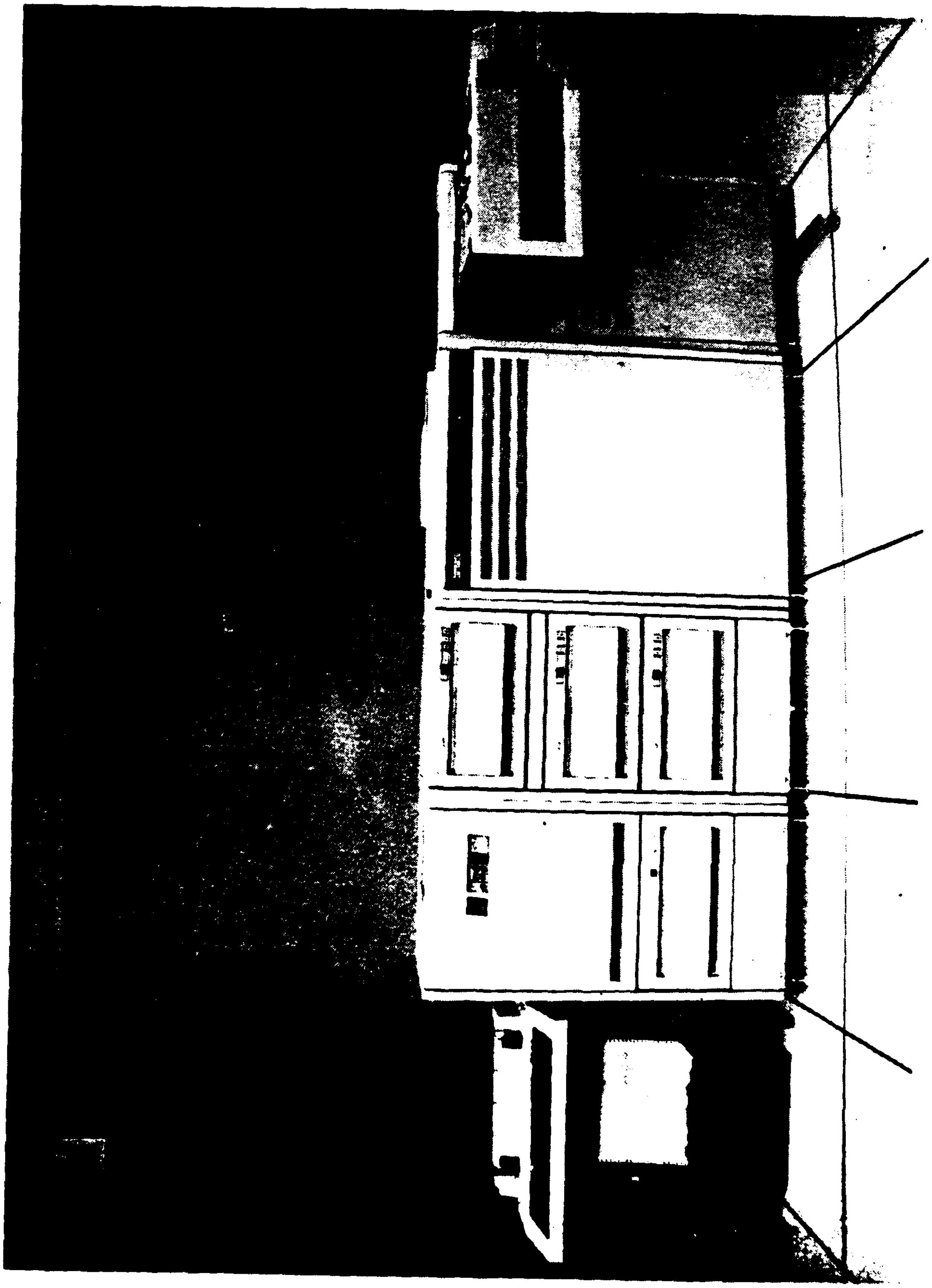


Figure 1-3 DEC VAX 11/750 Computer System

2.0 "AS-IS" ASSESSMENT

2.1 PWB Assembly Instructions

At Tracor Aerospace, the proper method for production of a PWB Assembly is defined by the Manufacturing Engineer via the Manufacturing Package. Information in this Manufacturing Package includes the sequence of manufacturing steps and the standard time calculated to perform each operation. As stated in the Tracor Standard Operation Procedure (SOP) 2023: "ME (Manufacturing Engineer) and QE (Quality Engineering) shall write a concise, accurate description that details how build and inspection operations are to be accomplished. The manufacturing process description shall include all required special tools, aids and "how to" instructions." Figure 2-1-1 shows an example of one page of a Manufacturing Package (prior to the CAPS project). This example shows the minimal information provided for seven operations written manually on a special form. This example also demonstrates the potential for mistakes. For instance, the text describing the proper machine was not completed for operation 60.

On occasion, a pictorial explanation is required to illustrate a manufacturing step such as the location to mark the serial number or the proper place to cut a trace on the PWB. Such sketches are added to the instruction sheet by maneuvering a large engineering drawing onto a photocopier, and then cutting and pasting part of the copy onto the appropriate page.

The minimal amount of information provided in the Manufacturing Package causes additional work to be performed by the assembly personnel. For example, setup information for the machines which prepare the components for manual insertion must be obtained by measuring a sample PWB for each part. Getting part number and reference designator information for the particular parts involved in each individual operation requires the operator to search the entire Parts List summary.

PART NUMBER	DESCRIPTION	PAGE	REVISION
H0479-0001	CCA, Driver Interface	3 OF 8	F-

S/U	OPERATION RUN	
	10	Verify material
.9		
	20	Mark board with last two digits of year, PWO No, and serial No as shown
.1	.025	in sketch provided. Refer to Note 5 of dwg.
		NOTE: Verify cleanliness of comp leads is sufficient to insure solderability. QC monitor.
	30	Vapor Spray clean board. QC monitor
	.008	
	40	Prep 9 caps (cut on HEPCO machine)
.1	.033	
	50	Prep 18 xstrs (cut on HEPCO machine)
.1	.051	
	60	Prep 2 caps (cut
.1	.010	
	70	Prep 7 resistors for stand-up mounting.
.1	.033	

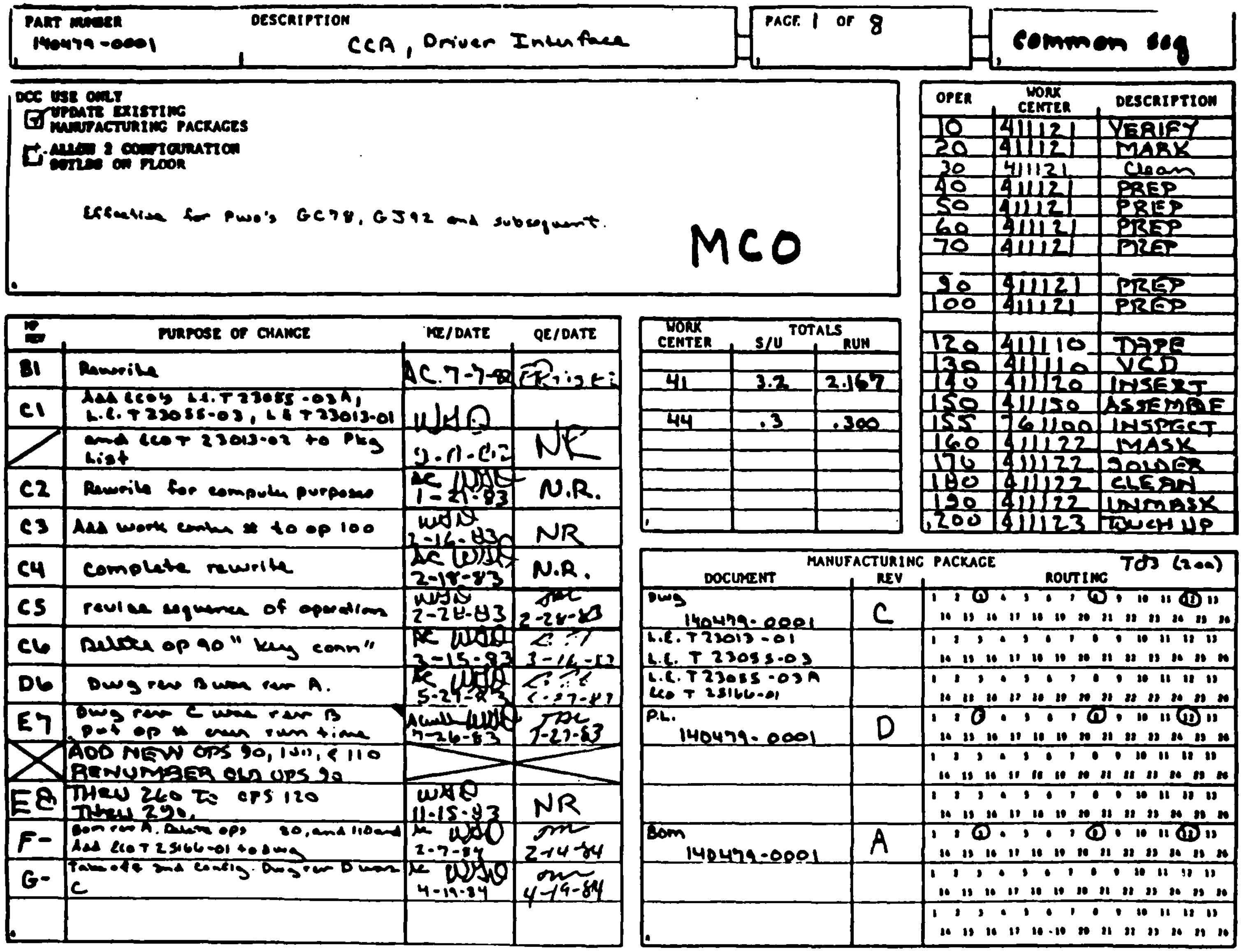
Figure 2-1-1 Example of "AS-IS" Manufacturing Instructions

Engineered time standards are manually calculated for each operation. For operations such as component prep and insertion, the number of components involved have to be counted in order to perform the time calculations, which is a time consuming activity obviously subject to human error.

Revisions to the Manufacturing Package are made using the provision in SOP 2023 which describes Manufacturing Change Orders. In this procedure, the corrected information is added using correction fluid ("white out") or the cut and paste method on the Manufacturing Package kept on file by the Manufacturing Engineers.

SOP 2023 further requires: "After completion of the operation pages, the ME and the QE will complete the cover page. The page, attached to the front of the operation pages, defines the manufacturing package contents and routing instructions." An example of a Cover Sheet is shown in Figure 2-1-2. It should be noted that the "Purpose of Change" block is used as a historical reference for revisions made to the instructions and only the last line is used to write in data (the whole block is not rewritten).

After the appropriate authorizing signatures, both new and revised Manufacturing Packages are forwarded to the Document Control Center. The Document Control Center makes photocopies and distributes them to the appropriate files. They are also responsible for inputting/updating the standard times (Bill of Labor) in the Tracor Manufacturing Control System (TMCS) via computer terminal connected directly to the UNIVAC mainframe computer. The operator manually inputs the setup and run time for each operation of the Manufacturing Package. In addition, for updating an existing Bill of Labor, the operator must compare the previous version with the latest revision to determine which values are to be modified. This manual input activity is labor intensive and, again, a potential source of errors.



PART NUMBER 140479-0001 | DESCRIPTION CCA, Driver Interface | PAGE 1 OF 8 | Common seq

DCC USE ONLY
- [x] UPDATE EXISTING MANUFACTURING PACKAGES
- [ ] ALLOW 2 CONFIGURATION OUTLETS ON FLOOR

Effective for PWO's GC78, GJ92 and subsequent.

MCO

OPER	WORK CENTER	DESCRIPTION
10	411121	VERIFY
20	411121	MARK
30	411121	Clean
40	411121	PREP
50	411121	PREP
60	411121	PREP
70	411121	PREP
90	411121	PREP
100	411121	PREP
120	411110	TAPE
130	411110	VCD
140	411120	INSERT
150	411150	ASSEMBLE
155	761100	INSPECT
160	411122	MASK
170	411122	SOLDER
180	411122	CLEAN
190	411122	UNMASK
200	411123	TOUCH UP

REV	PURPOSE OF CHANGE	ME/DATE	QE/DATE
B1	Rewrite	AC 7-7-82	[illegible]
C1	Add ECO's L.E. T23085-03A, L.E. T23055-03, L.E. T23013-01	WHO	
	and ECO T 23013-02 to Pkg list	9-11-82	NR
C2	Rewrite for computer purposes	AC WHO 1-21-83	N.R.
C3	Add work center ## to op 100	WHO 2-16-83	NR
C4	Complete rewrite	AC WHO 2-18-83	N.R.
C5	revise sequence of operations	WHO 2-28-83	[illegible] 2-28-83
C6	Delete op 90 "key conn"	AC WHO 3-15-83	[illegible] 3-16-83
D6	Dwg rev B was rev A.	AC WHO 5-24-83	[illegible] 5-27-83
E7	Dwg rev C was rev B Put op in own run time	WHO 7-26-83	[illegible] 7-27-83
	ADD NEW OPS 90, 100, & 110 RENUMBER OLD OPS 90		
E8	THRU 260 TO OPS 120 THRU 290.	WHO 11-15-83	NR
F-	Bom rev A. Delete ops 80, and 110 and Add ECO T 25166-01 to dwg	AC WHO 2-7-84	[illegible] 2-14-84
G-	Take off 2nd config. Dwg rev D was C	AC WHO 4-19-84	[illegible] 4-19-84

WORK CENTER	TOTALS S/U	TOTALS RUN
41	3.2	2.167
44	.3	.300

MANUFACTURING PACKAGE — TO3 (200)

DOCUMENT	REV	ROUTING
Dwg 140479-0001	C	1 2 3 4 5 6 7 8 9 10 11 12 13 / 14 15 16 17 18 19 20 21 22 23 24 25 26
L.E. T23013-01, L.E. T 23055-03		1 2 3 4 5 6 7 8 9 10 11 12 13 / 14 15 16 17 18 19 20 21 22 23 24 25 26
L.E. T23085-03A, ECO T 25166-01		1 2 3 4 5 6 7 8 9 10 11 12 13 / 14 15 16 17 18 19 20 21 22 23 24 25 26
P.L. 140479-0001	D	1 2 3 4 5 6 7 8 9 10 11 12 13 / 14 15 16 17 18 19 20 21 22 23 24 25 26
		1 2 3 4 5 6 7 8 9 10 11 12 13 / 14 15 16 17 18 19 20 21 22 23 24 25 26
		1 2 3 4 5 6 7 8 9 10 11 12 13 / 14 15 16 17 18 19 20 21 22 23 24 25 26
Bom 140479-0001	A	1 2 3 4 5 6 7 8 9 10 11 12 13 / 14 15 16 17 18 19 20 21 22 23 24 25 26
		1 2 3 4 5 6 7 8 9 10 11 12 13 / 14 15 16 17 18 19 20 21 22 23 24 25 26
		1 2 3 4 5 6 7 8 9 10 11 12 13 / 14 15 16 17 18 19 20 21 22 23 24 25 26

Figure 2-1-2 Example of "AS-IS" Cover Sheet

2.2 Auto Component Insertion Programming

There are currently three automated machines used in the insertion of components into Printed Wiring Boards. The Sequencer machine prepares a reel of axial components specially sequenced to correspond with the insertion pattern of the second machine, which is the Variable Center Distance (VCD) Axial Inserter. The third machine is the Dual Inline Package (DIP) Inserter, which sequences and inserts integrated circuits. Special ASCII language programs must be produced on each of the devices for each PWB Assembly targeted for auto component insertion. For the VCD Inserter, the information required for the program includes the location coordinates of the inserted components, the center distance between component leads, the component height, and the insertion sequence. The DIP Inserter requires the location coordinates of the components, the location of the part in the parts holding magazines, and the insertion sequence. The Sequencer requires the parts holding station number listed in reverse order of the insertion pattern defined by the VCD Inserter program.

Under the "AS-IS" condition the information required to operate the three automated machine was determined manually by measuring the appropriate dimension on the component or board. Then, a sample board in placed on the inserter and manually manipulated for each insertion location under the head of the machine. The x-y location value is then recorded. The task of programming the insertion equipment is done by the machine operators and the result of their effort is optimized only to the extent their expertise and time constraints will allow. Setup information is recorded manually on paper at the time of programming and kept on file in Auto Insertion.

2.3 PWB Assembly Testing

The Manufacturing Test Department was another area investigated by CAPS. Manufacturing Tests verifies the performance to requirements and reliability of deliverable electronic hardware. When PWB Assemblies were received from the assembly area, a test technician would set up the required test equipment, load a board onto the test fixture and run a series of pre-defined tests. If the PWB Assembly passed, the board was moved to the next operation noted on the production work order. If the PWB Assembly failed the test, the technician would notify Quality Control which would produce a Test Inspection Report (TIR) on the failed boards. The TIR is a permanent record on which all rework performed on the board is documented. The documented test procedure and type of test equipment utilized will determine the fault analysis process the technician will use. There are three types of test equipment configurations used: manual test, semi-automatic test, and automatic test. Manual tests may require the use of a hot mock-up, oscilloscope, meters, power supplies, and schematics, to isolate faults to the component or trace. Semi-automatic tests will locate the malfunctioning circuit, but may also require the use of an oscilloscope, meters, and schematics to isolate the faults. Automatic tests performed on the Hewlett-Packard HP 3060 isolates faults to the component or trace.

When the test technician determines what part(s) need to be ordered, a parts request status card is completed and submitted to Production Control. Production Control then uses the Tracor Manufacturing Control System (TMCS) to locate which stock account the part should be issued from and turns in the Material Requisition/Transfer Order (MRTO) to the appropriate stockroom. When the stockroom satisfies the request, it notifies Production Control which delivers the part to the requesting technician. The repair technician installs the part as designated on the TIR, and presents the board to inspection for approval.

2.4 PWB Assembly Repair

Repair of a nonconforming PWB Assembly is accomplished in three major steps. First, the PWB Assembly is tested by the Test Technician to identify the defect. Next he locates the defective component or trace, and the he marks it with an adhesive sticker and documents the problem. The board, along with the appropriate replacement parts, are then sent to a Repair Technician to initiate the actual repair. Major repairs to open lands are routed back to the Touchup area in PWB Assembly for repair. If the test is performed on automated test equipment, the identification step is significantly more efficient, since the defects are identified by a paper readout listing the faulty component's reference designator or trace's node name. However, the technician must then refer to the schematic and search on the actual PWB Assembly to locate and mark the defect. If replacement parts are required, he must refer to the Parts List to obtain the proper Tracor part number, then complete the order. Once the Repair Technician completes the repair, the PWB Assemblies are inspected and rerouted through the test procedure. This cycle is repeated as required until an acceptable PWB Assembly is produced.

2.5 PWB Identification

One of the initial operations in the production of Printed Wiring Board Assemblies is the marking of information onto the bare PWB (without components). The type of information affixed to each board varies depending on the requirements of the product. All boards require as a minimum, a serial number and assembly revision letter. Other information which might be marked on a board as well includes the Production Work Order (PWO) number, a reference designator, the assembly dash number, and the last two digits of the current year. The information marked on the boards must remain legible under the same environmental conditions required of the PWB Assembly itself as

defined by MIL-STD 810C. Currently, the information is applied to the board manually using a special nonconductive, indelible ink and a metal quill pen. The ink is a two-part compound (DEXTER HYSOL CAT-L-INK and CATALYST) which must be prepared daily. The process of writing legible numbers and letters in a very small area on the PWB is a tedious task subject to human errors which require immediate correction. The serial numbers are recorded manually on the back of the PWO documents to serve as a log of the numbers used.

3.0 "TO-BE" ASSESSMENT

3.1 PWB Assembly Instructions

The goal of the CAPS Instruction Sheet Generator is to aid Manufacturing Engineering in providing detailed information to Manufacturing at minimal cost and in a timely manner. The CAPS Instruction Sheet Generator utilizes computer technology to access key information from Computer Aided Design (CAD) and the Tracor Manufacturing Control System (TMCS) in a real time environment, thus minimizing the amount of manual calculation and data entry required to produce the Manufacturing Package.

The number of tasks typically required in the PWB Assembly process is finite regardless of the design of the board. Almost all boards must flow through operations for marking, component prep, component insertion, inspection, wave solder, secondary assembly, touchup, and final inspection. The tasks within each operation are also fairly repetitive, utilizing the common manufacturing resources located in the area. It is this common denominator of manufacturing methods which allows for the development of a set of standard manufacturing instructions, with associated standard times. In the CAPS system, each standard manufacturing instruction is assigned a three letter "Method Code". This "Method Code" is then given an appropriate standard time taken from generally-accepted predetermined time manuals. The Method Code facilitates computer manipulation of the data, thereby reducing manual data input and arithmetic calculations. In addition, the Method Codes can be analyzed for frequency of occurrence to pinpoint potential areas for method improvements.

Certain tasks require information unique to the design of the PWB Assembly, such as the length to cut a jumper wire or the number of holes to be masked. In CAPS, provisions are made for inputing up to two variables for each Method Code,

which are defined as either text to be printed verbatim, or numbers to be used in calculating time standards. Inclusion of material information used within each operation is accomplished through the input of the appropriate item number listed in the Bill of Material, downloaded from TMCS. Any other unique information can be input verbatim using the "free text" option provided within CAPS.

Custom software was developed on the VAX computer which allows the Manufacturing Engineer to input, via VT240 computer terminals, the appropriate Method Codes and variables required to produce detailed instruction sheets. A series of menus allows the M.E. to choose the steps required to accomplish the task, whether it be writing a new instruction sheet, revising a current instruction sheet, or maintaining the data bases where the Method Codes and other information are defined. The process flow diagram for generation of instruction sheets is shown in Figure 3-1-1. Details on the exact procedure for any specific process are defined in the Software Documentation Appendix I of this proposal.

Basically, the M.E. enters onto a formatted "Input Sheet" screen the operation number, name, and work center. Then the appropriate (pre-defined) Method Code is selected and entered, along with the item number of material involved, if any, and variable information, if required. The remainder of the Input Sheet line is filled in automatically with material description and reference designator, partial description of the manufacturing instruction and the associated standard time. If the material item number has a multiple quantity with different reference designators, additional Input Sheet lines will be automatically filled in for each reference designator, thereby reducing the inputs required by the M.E. If CAD information is available, variables defining the lead spacing information for Component Prep operations are automatically calculated and input to the proper variable field. The Manufacturing Engineer

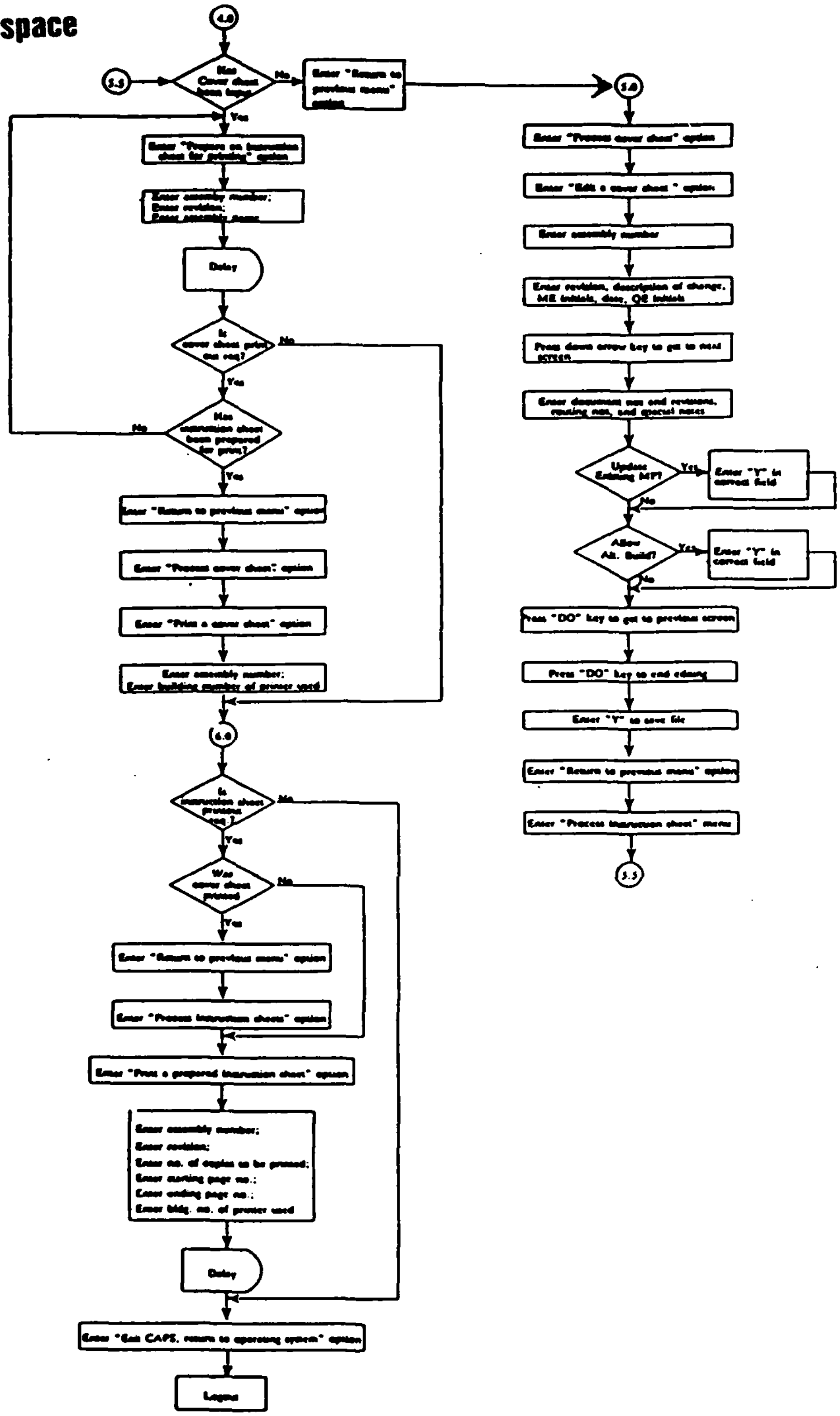


Figure 3-1-1 Write An Instruction Sheet Using CAPS

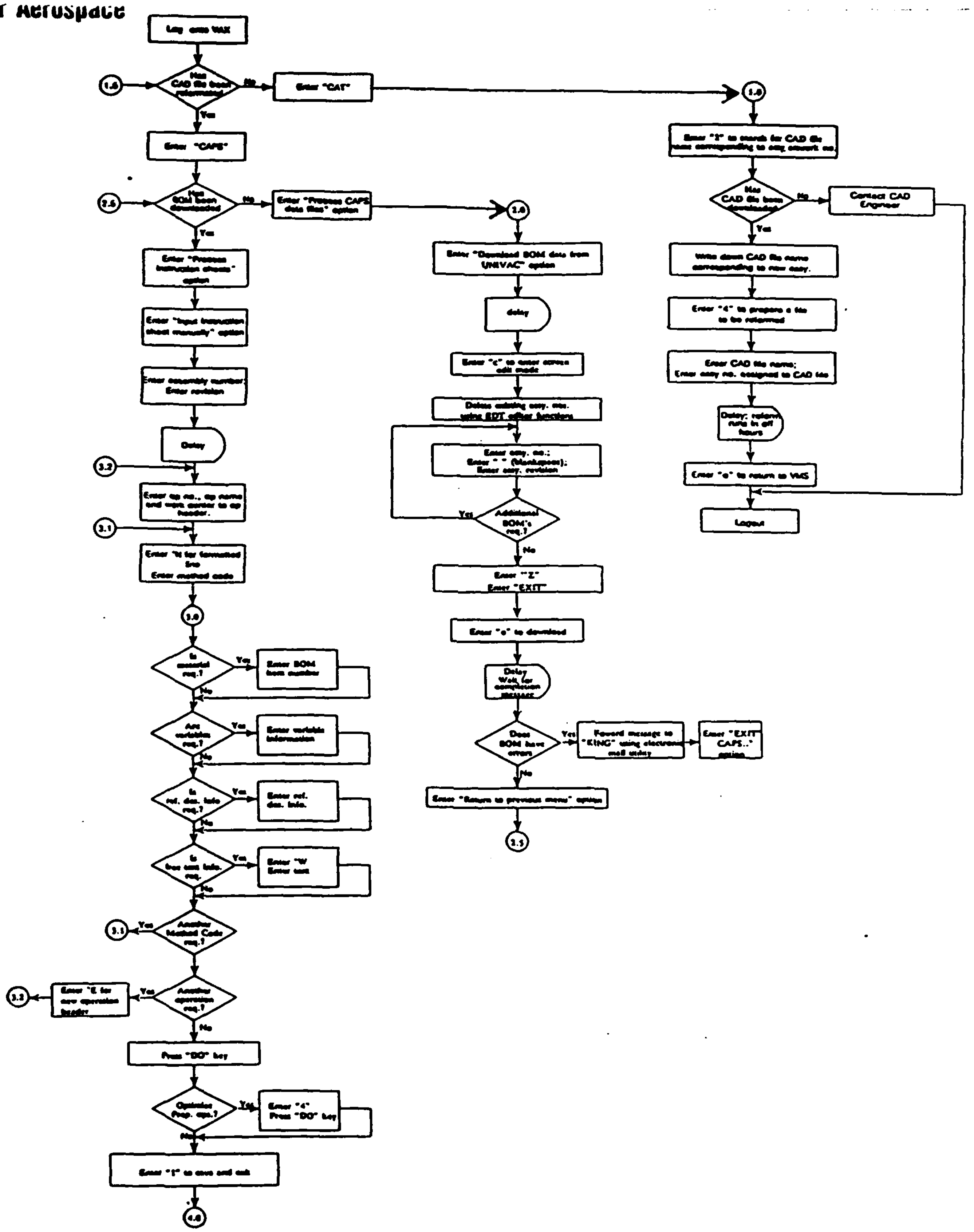


Figure 3-1-1 Write An Instruction Sheet Using CAPS (cont.)

completes additional Input Sheet lines for each material item and/or Method Code involved in the operation. This basic procedure is repeated for each operation in the manufacturing process. The CAPS Instruction Sheet Generator software then transforms the abbreviated format of the Input Sheet into the expanded Instruction Sheets used in production. Time standards are automatically calculated for each operation based on the predetermined times established for each Method Code. An example of a CAPS instruction set is shown in Figure 3-1-2.

Instruction Sheets produced using CAPS provide the vital information required to properly setup many of the operations in PWB Assembly. For the "Stage" operation, a summary is shown of the operations involved in the assembly, and the material associated with each of those operations. This information assists in the distribution of material at the beginning of a production run to the appropriate workstations. For operations where tasks are performed on individual parts, detailed information is provided for each of those parts, including the Tracor part number, a functional description, and the reference designator, if applicable. For component prep operations, lead spacing and lead length specifications are provided to assist in prep machine setup. A provision in the CAPS software allows the M.E. to optimize this setup information by arranging the lead spacing in ascending order to avoid repetition of setups. Also, for most operations, a "target" production time is calculated in pieces per minute or boards per hour based on the engineered time standard which provides a benchmark for manufacturing. The text of the instructions is more complete and is consistent, regardless of the individual producing them. The time standards are correspondingly more consistent and, again, are based on predetermined times or stopwatch time studies which should satisfy the requirements of MIL-STD 1567A.

PART NUMBER	DESCRIPTION	PAGE OF	PROGRAM
140479-0001	CCA, DRIVER INTERFACE	1 43	COMMON SEQUENCER

MP REV	PURPOSE OF CHANGE	MFG ENG DATE	QUAL ENG DATE
M-	PL REV C WAS B. RENUMBER PAGES	AC 05/30/86	CJH 06/02/86
N-	ADD ECO T30173-00 TO PL. ADD OP 220. BOM TO REV. C.	RB 06/23/86	DCL 06/24/86
P-	BOM TO REV. F. REVISE OPS 020, 150, 220, 250, & 400. ADD ECO T30353-00 TO PL	RB 08/22/86	DL 08/22/86
Q-	ADD SUPERSEDING ECO T30173A00 TO PL. BOM TO REV. G. REVISE OP 050. ADD OP 520	RB 09/06/86	DL 09/08/86
Q1	ADD OPS 350, 530, 540 & 550. REVISE OPS 020, 400 & 430. DELETE OP 520.	RB 09/15/86	DL 09/15/86
R-	PL TO REV. D. ADD OP 685. DELETE OP 495. REVISE OPS 430, 500, 510, & 695.	RB 10/13/86	DL 10/13/86
S-	PL TO REV. E. ADD HANDLING INSTRUCTIONS TO COVER PAGE. REVISE OP 699,799,949,950	RB 10/22/86	DL 10/22/86
S1	REVISE OP 020, 400, 610, 699, 700, 799, & 840.	10/30/86	/ /
		/ /	/ /
		/ /	/ /

OPER	WORK CENTER	DESCRIPTION	SETUP	RUN
0010	411121	VERIFY.	0.7	0.000
0020	411121	STAGE.	0.7	0.000
0050	411121	MARK.	0.3	0.038
0100	411121	PREP.	0.7	0.012
0110	411121	PREP.	0.1	0.075
0120	411121	PREP.	0.1	0.018
0140	411121	PREP.	0.1	0.004
0150	411121	PREP.	0.1	0.029
0220	411121	TIN.	0.1	0.038
0250	411110	SEQUENCE.	2.5	0.009
0260	411110	VCD INSERT.	0.5	0.021
0280	411110	VERIFY A/I.	0.1	0.031
0350	411120	MASK.	0.1	0.051
0400	411120	ASM-MECH.	0.1	0.115
0430	411120	ASM-INSERT.	0.3	0.065
0500	411122	BAKE.	0.1	0.001
0510	411122	SOLDER.	0.3	0.047
0530	411122	UNMASK.	0.0	0.037
0540	411120	INSTALL.	0.1	0.043
0550	411125	SOLDER.	0.1	0.020
0600	411123	TOUCHUP.	0.1	0.118
0610	411123	CLEAN.	0.1	0.007
0685	761100	INSPECT.	0.0	0.000
0695	761100	INSPECT.	0.0	0.000
0699	360000	TOLLGATE 3.	0.0	0.000
0700	441100	TEST.	0.3	0.312
0799	360000	TOLLGATE 8.	0.0	0.000
0820	411130	COAT.	0.3	0.058
0830	411130	COAT.	0.1	0.043
0840	411130	UNMASK.	0.2	0.025
0945	761200	INSPECT.	0.0	0.000
0949	360000	TOLLGATE 12.	0.0	0.000
0950	360000	STOCK.	0.0	0.000

MANUFACTURING PACKAGE

DOCUMENT	REV.	TOLL GATE ROUTING
DWG 140479-0001	E	3, 8, 12
PL 140479-0001	E	3, 8, 12
BOM 140479-0001	G	3, 8, 12

SPECIAL NOTES

■ UPDATE EXISTING MANUFACTURING PACKAGE

☐ ALLOW ALTERNATE BUILD CONFIGURATIONS

****
HANDLING INSTRUCTIONS
****
FOR TRANSFER BETWEEN WORK AREAS, CCA'S SHALL BE PACKED, WITHOUT BAGS, IN COVERED "IBC" CARRIERS. THIS INCLUDES: PWB-TO-TEST
TEST-TO-COAT
COAT-TO-STOCK
RETURN EMPTY CARRIERS TO PWB DEPT.

Figure 3-1-2 Example of New Instruction Set

For those occasions in which a pictorial representation of the board is needed to clarify an instruction, software is developed to produce a hardcopy printout of the PWB Assembly onto a letter size paper. Three types of pictorials are available: 1)an outline of the board with the components outlined, 2) an outline of the board showing the traces on the top side, 3) an outline of the board showing the traces on the bottom side. These provide considerably more accuracy than the sketches and photocopies previously used.

The Cover Sheet associated with the Instruction Sheet is also produced using the CAPS Instruction Sheet Generator. Once again, the M.E. chooses the appropriate menu options to access a specially formatted screen on the VT240 terminal and some of the required information, such as the purpose of the change and list of documents in the manufacturing package, is input. The remaining required information, the routing instructions and the assembly time standards, is automatically input via software which accesses the data previously input during the instruction sheet generation process.

The Instruction Sheet and Cover Sheet are printed out using a Printronix printer and the resulting Manufacturing Package is routed for the appropriate signatures. The Manufacturing Package is then forwarded to the Document Control Center so that photocopies can be made and distributed to the appropriate files. The Document Control Center also initiates the CAPS software routine for automatic upload of Bill of Labor data to TMCS. This routine replaces the manual effort of inputting data with a system that automatically compares the Bill of Labor presently in TMCS with the data which was electronically stored as a result of the generation of the Cover Sheet using the CAPS Instruction Sheet Generator. The difference between the two files is then automatically updated in TMCS. For new PWB Assemblies, the full Bill of Labor produced from CAPS is uploaded automatically.

Revisions to the Manufacturing Package due to Design Engineering or Manufacturing Engineering changes are significantly simplified with the CAPS Instruction Sheet Generator since the data can be edited electronically and reprinted. The process flow diagram for generation of revised instruction sheets is shown in Figure 3-1-3. Revisions due to general manufacturing process changes are also simplified due to the development of an automatic update function. With this function, a change in the Method Code information (text or time standard) will automatically be incorporated in any Input Sheet being edited (for any reason) by merely pressing a pre-defined function key. To determine which PWB Assemblies require editing, the Method Code Analysis function is employed to search all Input Sheet files for occurrences of that code.

3.2 Auto Component Insertion Programming

The goal of the Auto Component Insertion Programming portion of CAPS was to improve the efficiency of the Auto Insertion operation by using computer technology to produce optimized insertion and setup information. The CAPS Insertion Program Generator utilizes data from CAD for board/component location and orientation, from TMCS for material part number and descriptive information, and from the Component Data File on the VAX for dimensional information on individual components. In addition to the data transfer links, electronic communications are established between the Design Engineers and the M.E., and between the M.E. and the insertion machine operators, to insure that the M.E. will be cognizant of any design or insertion program changes. The security of the insertion programs is enhanced, since they are stored on the VAX computer system, where files are backed up on magnetic tape daily.

When a new or revised PWB Assembly design produced on the RACAL/REDAC Computer Aided Design system is released for production, the Design Engineer initiates a special procedure for

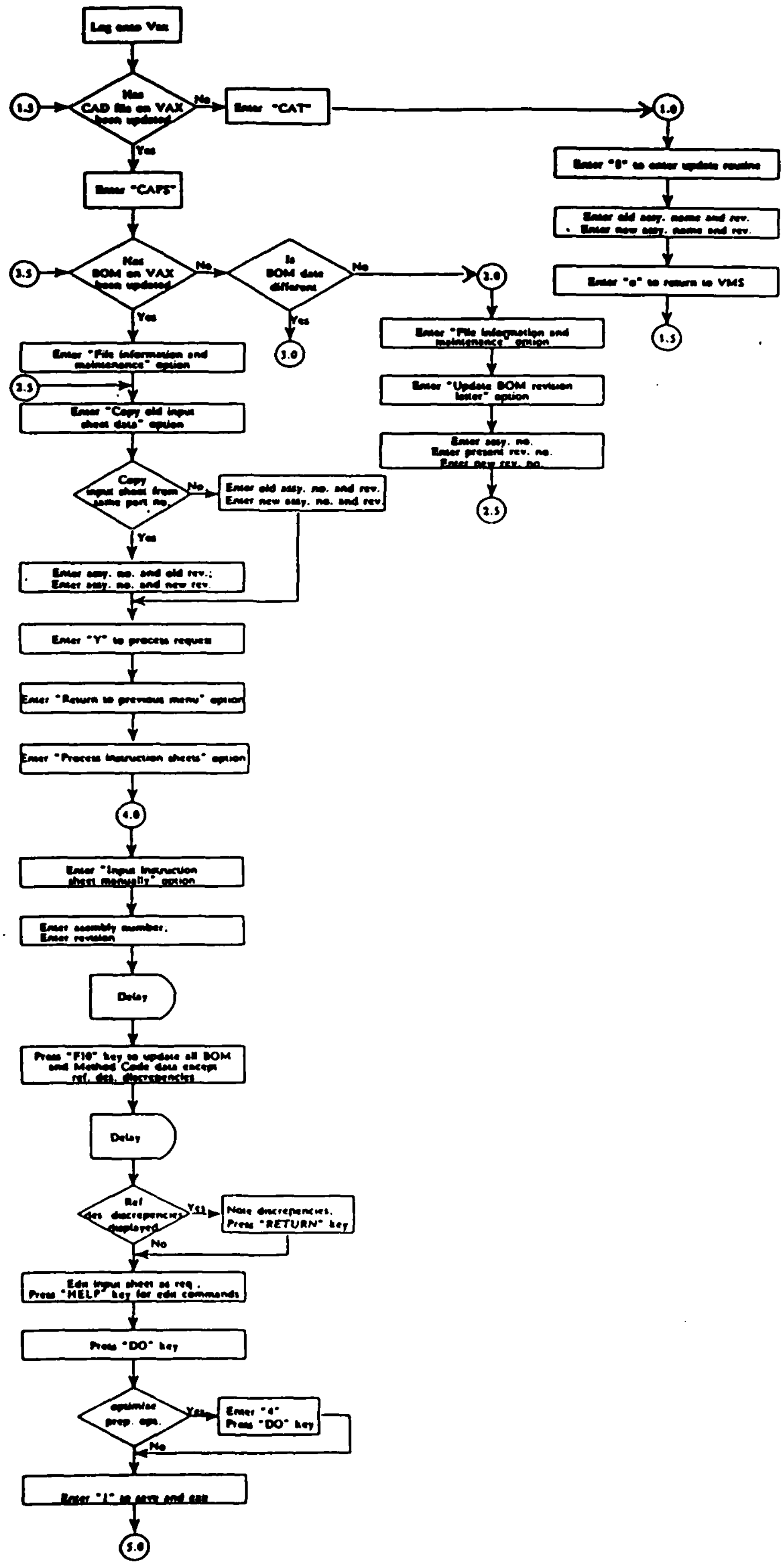


Figure 3-1-3 Revise An Instruction Sheet Using CAPS

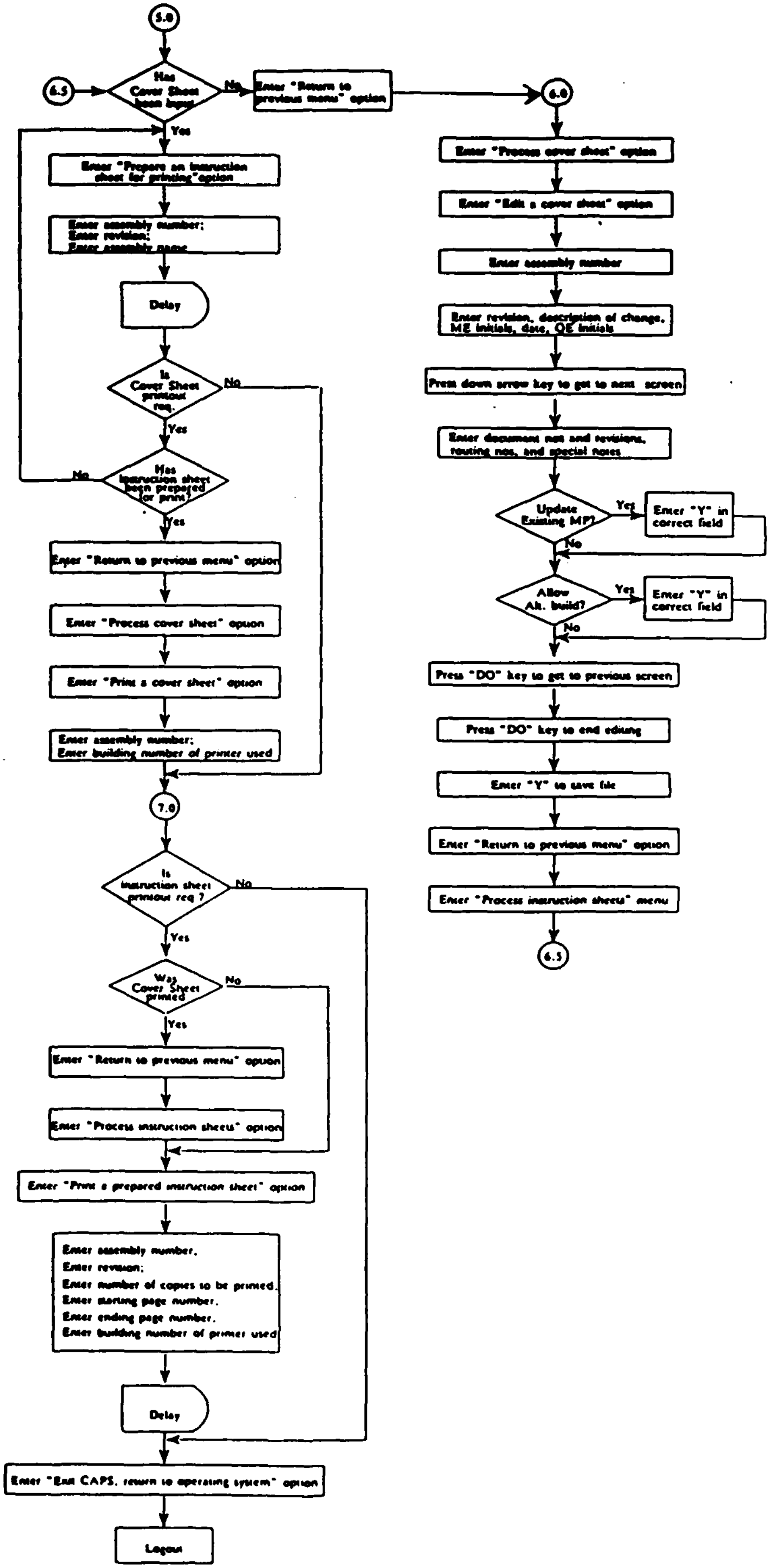


Figure 3-1-3 Revise An Instruction Sheet Using CAPS (cont.)

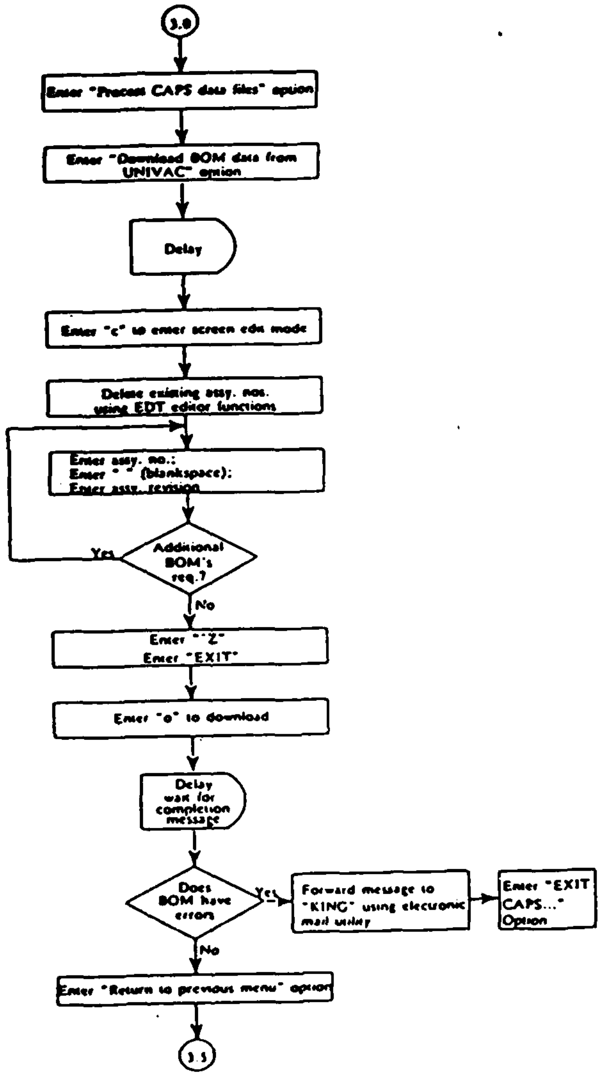


Figure 3-1-3 Revise An Instruction Sheet Using CAPS (cont.)

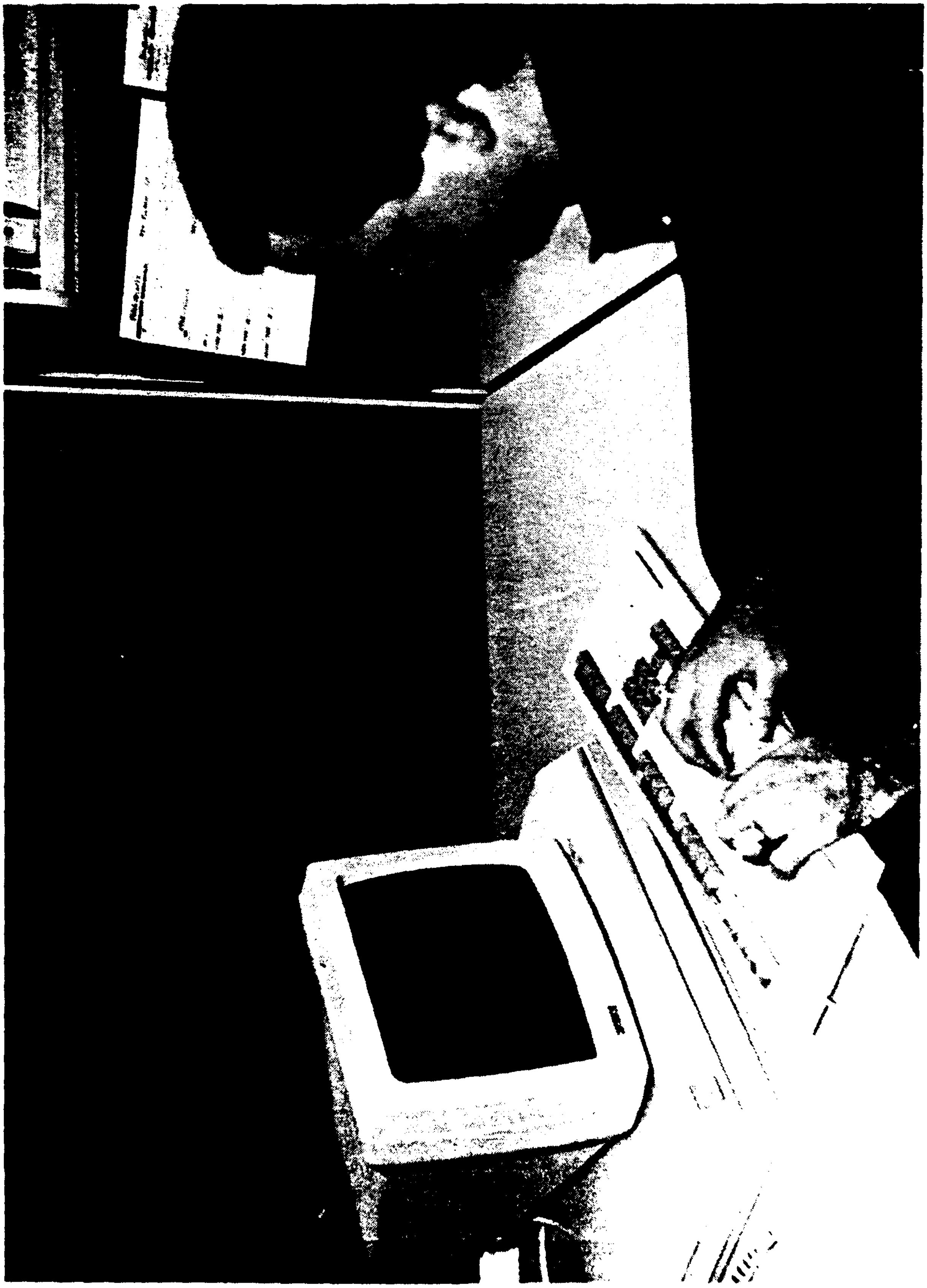


Figure 3-1-4 Generate Manufacturing Instructions Using CAPS Terminal

downloading the design data file to the VAX computer in Manufacturing. The M.E. is electronically notified of the download via the mail utility on the VAX and, after downloading the associated BOM from TMCS, he initiates the "Reform" software routine prior to the next effective production run. "Reform" is a software routine which translates the format of the data as received from CAD to a format compatible with the three applications in CAPS: 1) Component prep data for the Instruction Sheet Generator, 2) Component location and orientation on the board for the Auto Component Insertion Programming, and 3) Board, trace, and hole size and location for the Computer Aided Repair work station.

In addition to CAD and BOM data, the CAPS Insertion Program Generator requires certain data relating to the design of the board holding fixture and the setup restrictions of the insertion equipment. A special communication system is installed between the VAX and the two controllers for the insertion equipment using a microcomputer as a coordinator/translator/input/output device. Software is developed so that the machine operators can input information for: 1) Board orientation on the fixture, 2) Insertable components purposely excluded from insertion, 3) Grouping and exclusion of windows on the fixture for each insertion pattern, 4) Location of reference pin offset for each window, 5) Number of windows on a fixture, 6) Inactive inserter parts holders, and 7) Preassignment of parts to parts holder locations. The process flow diagram for generation of Component Insertion programs is shown in Figure 3-2-1. Details on the exact procedure for the process are defined in the Software Documentation Section, Appendix I of this proposal

After all of the required information is supplied, the CAPS Program Generator will be activated by the machine operators to produce the actual insertion programs requested and the instructions for setup of the components to correspond to the program. This request is initiated by the machine operators

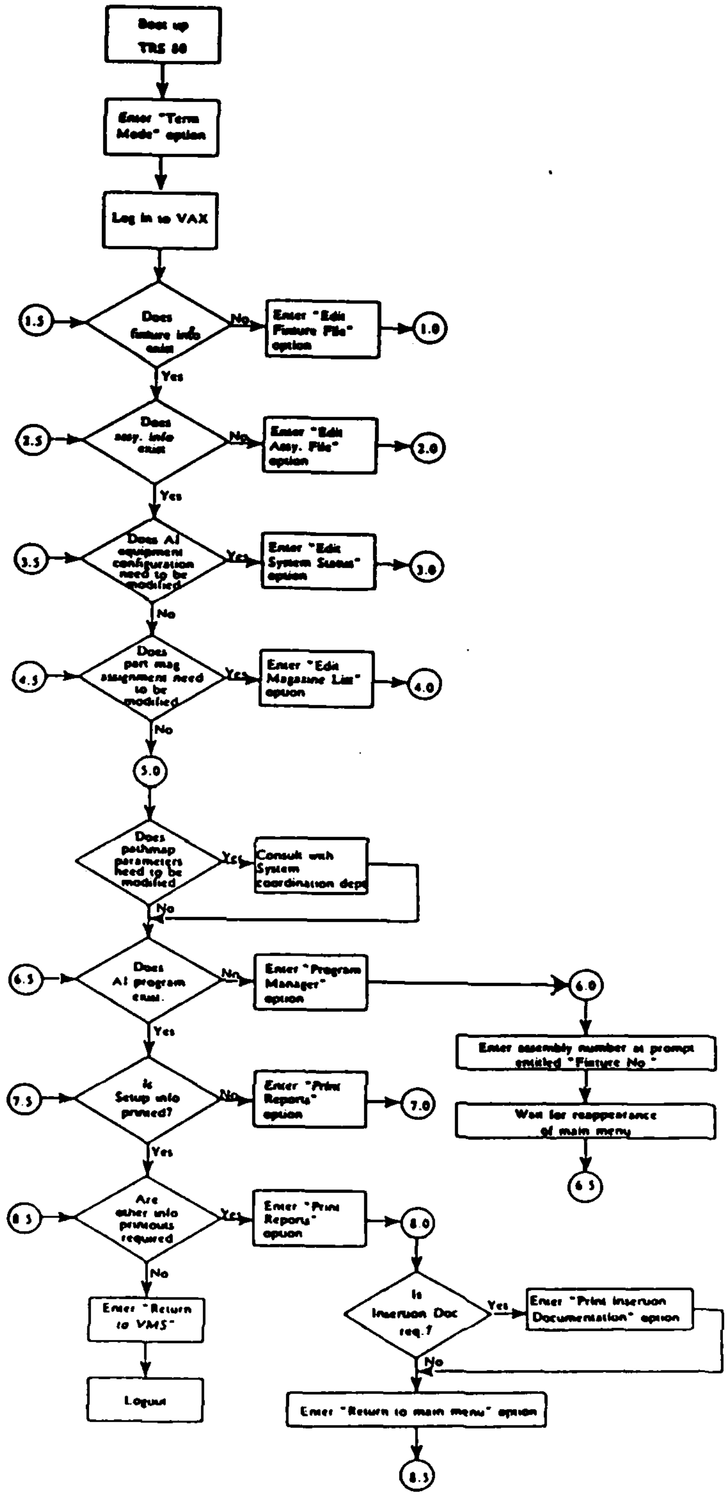


Figure 3-2-1 Generate Component Inserter Program Using CAPS

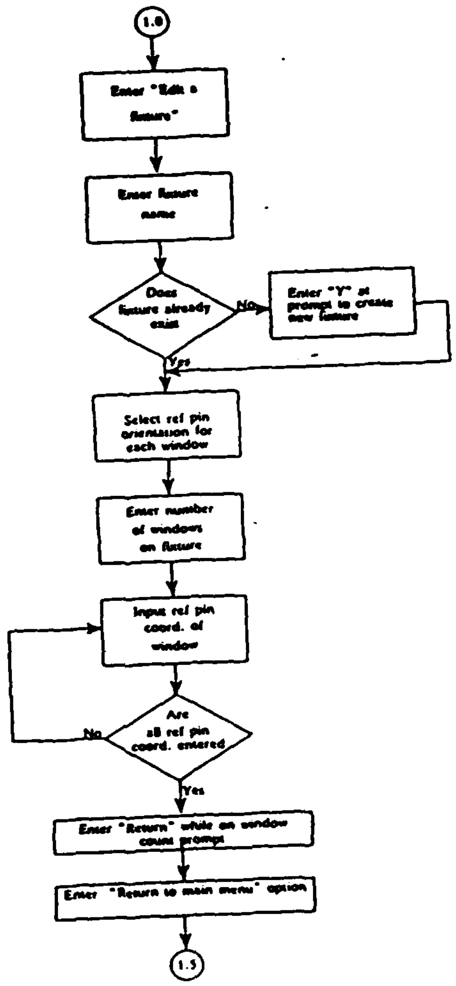


Figure 3-2-1 Generate Component Inserter Program Using CAPS (cont.)

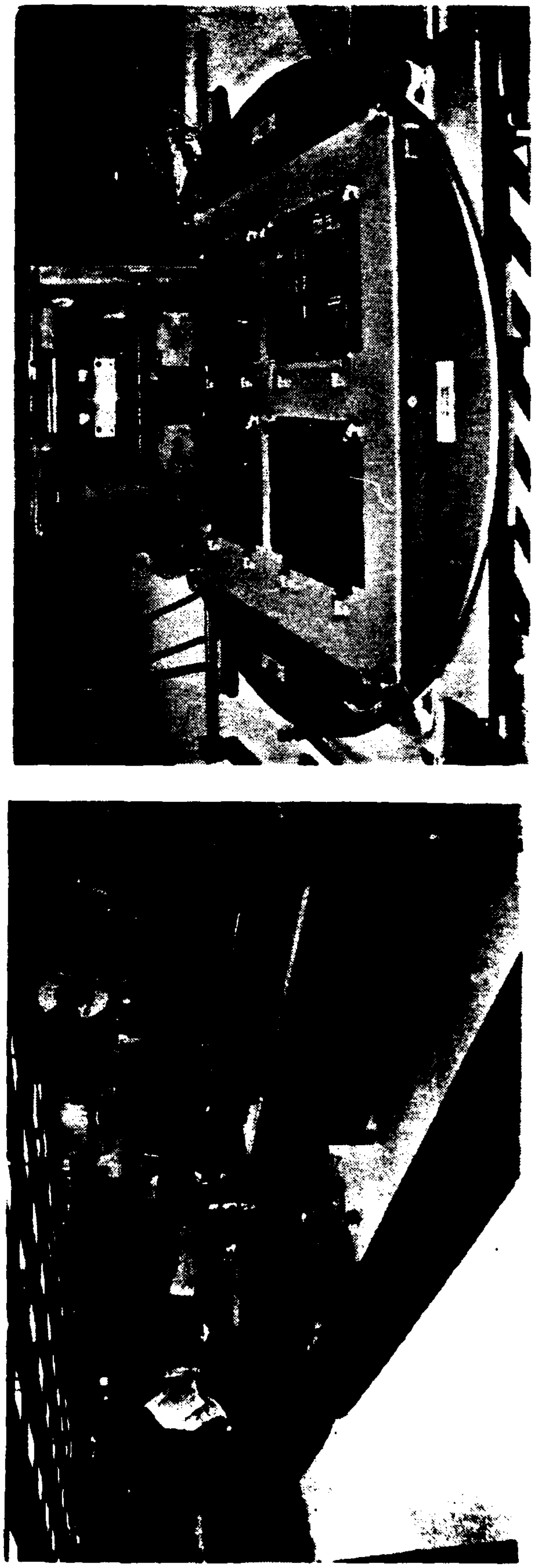


Figure 3-2-2 Auto Component Insertion Machines and Holding Fixture

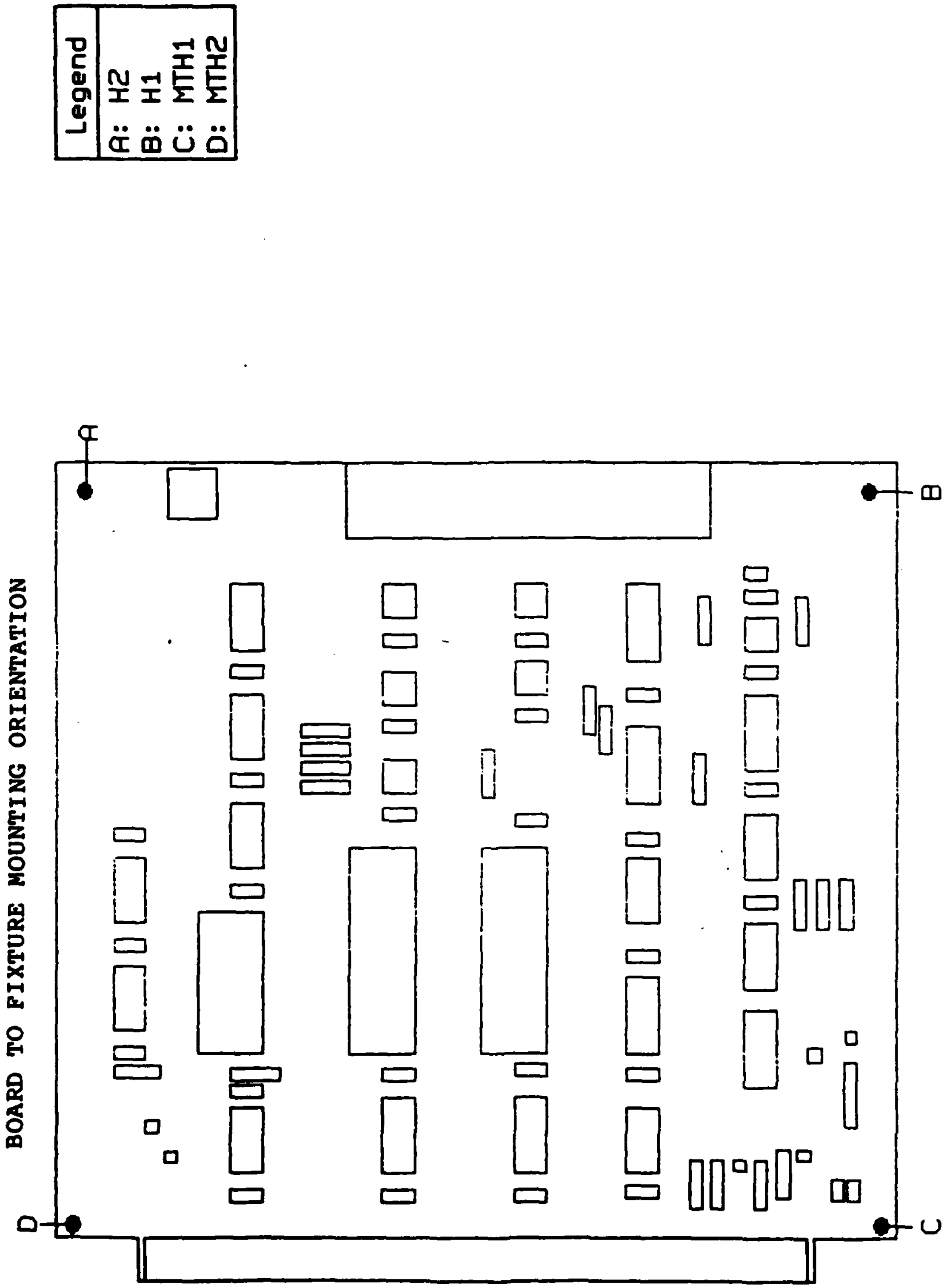


Figure 3-2-3 Component Inserter Set-Up Information

SEQUENCER MATERIAL SET-UP

Date: Time : Assembly:

Pri/Sec Mag	Ref Desig	Part Number	BOM Qty	Ins Qty	Description	I.D. Number	Ins Seq	Pin 1
1/ 0	R15	24750-0102	9	18	RES CMPSN1K 1/4W	RCR07G102JS		L

Pri/Sec Mag	Ref Desig	Part Number	BOM Qty	Ins Qty	Description	I.D. Number	Ins Seq	Pin 1
1/ 0	R15	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	1	L
1/ 0	R13	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	2	L
1/ 0	R14	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	3	L
1/ 0	R13	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	4	L
1/ 0	R14	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	5	L
1/ 0	R15	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	6	L
1/ 0	R9	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	7	L
1/ 0	R10	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	8	L
1/ 0	R11	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	9	L
1/ 0	R12	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	10	L
1/ 0	R4	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	11	L
1/ 0	R5	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	12	L
1/ 0	R5	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	13	L
1/ 0	R4	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	14	L
1/ 0	R9	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	15	L
1/ 0	R10	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	16	L
1/ 0	R11	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	17	L
1/ 0	R12	24750-0102	1	1	RES CMPSN1K 1/4W	RCR07G102JS	18	L

Figure 3-2-3 Component Inserter Set-Up Information (Cont.)

DIP INSERTER MATERIAL SET-UP

Date: Time Assembly:

Pri/Sec Mag	Ref Desig	Part Number	BOM Qty	Ins Qty	Description	I. D. Number	Ins Seq	Pin 1
237/238	U11	24634-0071	4	8	IC 4-BIT BUS DRIVER	8216		R
236/235	U25	24634-0261	4	8	IC DIFF LINE DRVR	9638TC		R
239/240	U21	24634-0181	2	4	IC DIFF LINE RCVR	9637ATC		R
234/233	U12	24634-0146	2	4	IC HEX INVERTER	SN74LS04N		R
241/242	U27	24634-0143	1	2	IC 2-INPUT NOR GATE	SN74LS02N		R
232/231	U26	24634-0167	1	2	IC 3-INPUT NAND GATE	SN74LS10N		R
243/244	U18	24634-0147	1	2	IC 2-INPUT NAND GATE	M74LS00P		R
230/229	U8	24201-0025	1	2	IC INPUT NOR GATE	SN7425N		R
245/246	U17	24634-0165	1	2	IC SN74LS138N	SN74LS138N		R
228/227	U28	24634-0173	1	2	IC HEX BUFFER 4-2 BIT	SN74LS367N		R
247/248	U9	24634-0166	1	2	IC 2-INPUT OR GATE	SN74LS32N		R

Pri/Sec Mag	Ref Desig	Part Number	BOM Qty	Ins Qty	Description	I. D. Number	Ins Seq	Pin 1
239/240	U21	24634-0181	1	1	IC DIFF LINE RCVR	9637ATC	1	R
237/238	U11	24634-0071	1	1	IC 4-BIT BUS DRIVER	8216	2	R
236/235	U25	24634-0261	1	1	IC DIFF LINE DRVR	9638TC	3	R
236/235	U23	24634-0261	1	1	IC DIFF LINE DRVR	9638TC	4	R
236/235	U22	24634-0261	1	1	IC DIFF LINE DRVR	9638TC	5	R
236/235	U24	24634-0261	1	1	IC DIFF LINE DRVR	9638TC	6	R
237/238	U1	24634-0071	1	1	IC 4-BIT BUS DRIVER	8216	7	R
237/238	U10	24634-0071	1	1	IC 4-BIT BUS DRIVER	8216	8	R
239/240	U20	24634-0181	1	1	IC DIFF LINE RCVR	9637ATC	9	R
234/233	U12	24634-0146	1	1	IC HEX INVERTER	SN74LS04N	10	R
241/242	U27	24634-0143	1	1	IC 2-INPUT NOR GATE	SN74LS02N	11	R
234/233	U13	24634-0146	1	1	IC HEX INVERTER	SN74LS04N	12	R
232/231	U26	24634-0167	1	1	IC 3-INPUT NAND GATE	SN74LS10N	13	R
237/238	U2	24634-0071	1	1	IC 4-BIT BUS DRIVER	8216	14	R
243/244	U18	24634-0147	1	1	IC 2-INPUT NAND GATE	M74LS00P	15	R
230/229	U8	24201-0025	1	1	IC INPUT NOR GATE	SN7425N	16	R
245/246	U17	24634-0165	1	1	IC SN74LS138N	SN74LS138N	17	R
228/227	U28	24634-0173	1	1	IC HEX BUFFER 4-2 BIT	SN74LS367N	18	R
247/248	U9	24634-0166	1	1	IC 2-INPUT OR GATE	SN74LS32N	19	R
239/240	U21	24634-0181	1	1	IC DIFF LINE RCVR	9637ATC	20	R
237/238	U11	24634-0071	1	1	IC 4-BIT BUS DRIVER	8216	21	R
236/235	U25	24634-0261	1	1	IC DIFF LINE DRVR	9638TC	22	R
236/235	U23	24634-0261	1	1	IC DIFF LINE DRVR	9638TC	23	R
236/235	U22	24634-0261	1	1	IC DIFF LINE DRVR	9638TC	24	R
236/235	U24	24634-0261	1	1	IC DIFF LINE DRVR	9638TC	25	R
237/238	U1	24634-0071	1	1	IC 4-BIT BUS DRIVER	8216	26	R
237/238	U10	24634-0071	1	1	IC 4-BIT BUS DRIVER	8216	27	R
239/240	U20	24634-0181	1	1	IC DIFF LINE RCVR	9637ATC	28	R
234/233	U12	24634-0146	1	1	IC HEX INVERTER	SN74LS04N	29	R
241/242	U27	24634-0143	1	1	IC 2-INPUT NOR GATE	SN74LS02N	30	R
234/233	U13	24634-0146	1	1	IC HEX INVERTER	SN74LS04N	31	R
232/231	U26	24634-0167	1	1	IC 3-INPUT NAND GATE	SN74LS10N	32	R
237/238	U2	24634-0071	1	1	IC 4-BIT BUS DRIVER	8216	33	R
243/244	U18	24634-0147	1	1	IC 2-INPUT NAND GATE	M74LS00P	34	R
230/229	U8	24201-0025	1	1	IC INPUT NOR GATE	SN7425N	35	R
245/246	U17	24634-0165	1	1	IC SN74LS138N	SN74LS138N	36	R
228/227	U28	24634-0173	1	1	IC HEX BUFFER 4-2 BIT	SN74LS367N	37	R
247/248	U9	24634-0166	1	1	IC 2-INPUT OR GATE	SN74LS32N	38	R

Figure 3-2-3 Component Inserter Set-Up Information (Cont.)

```
                       INSERTION EXCEPTIONS LIST
**************************************************************************
**  Time:                 Date:                 Assembly:               **
**************************************************************************

Component witheld by program.
Reference Designator: //*\\
Part Number         :
Engineering Ref. No.:
Description         :
Reason              : No such component in cross_reference file.

Component witheld by program.
Reference Designator: BOARD
Part Number         :
Engineering Ref. No.:
Description         :
Reason              : No such component in cross_reference file.

Component witheld by program.
Reference Designator: C1
Part Number         :
Engineering Ref. No.:
Description         :
Reason              : No such component in BOM file.

Component witheld by program.
Reference Designator: R16
Part Number         :
Engineering Ref. No.:
Description         :
Reason              : No such component in BOM file.

Component witheld by program.
Reference Designator: R17
Part Number         :
Engineering Ref. No.:
Description         :
Reason              : No such component in BOM file.
```

Figure 3-2-3 Component Inserter Set-Up Information (Cont.)

instead of the M.E. so that temporary modifications can be rapidly accommodated. The M.E. is automatically notified via the mail utility of the VAX of permanent changes so that he can investigate the situation and, if warranted, process the associated modifications to the Instruction Sheet.

The final result of the CAPS Program Generator is a computer-optimized insertion program for each requested machine in ASCII language which is uploaded to the appropriate machine controller electronically. The setup information, as shown in Figure 3-2-3, is printed on a Printronix printer connected to the VAX computer.

3.3 PWB Assembly Testing

From a cycle time standpoint, the most effective technique for identifying functional non-conformance on a PWB Assembly is through the use of automated test equipment such as the Hewlett Packard HP 3065. This equipment utilizes custom vacuum fixtures with special spring-loaded contact pins located precisely to correspond with key nodes on the PWB. The PWB Assembly is placed onto the fixture, the vacuum is actuated, and the board makes electrical contact with the pins. The pins are the interface between the PWB Assembly and the computer intelligence of the automated tester. Custom software is developed to test the values of the individual components on the board for conformance to the tolerance requirements of the board design. Those components not meeting the required specifications are noted on a machine print out which lists the defects for further action. Tests are likewise run on traces to identify shorts or opens which affect the designed function.

To increase the utilization of the Automated Test Equipment and thereby decrease the time associated with the identification of defects, research was conducted to compile a target list of PWB Assemblies to be converted from manual and

semi-automatic to automatic procedures. Of the 30 PWB Assemblies originally considered, all but eight were removed from consideration because they were covered under other contracts, or major design changes were anticipated which would have obsoleted the custom software and hardware soon after creation.

Original plans called for the selected boards to be converted for testing on the HP 3060 Auto Test Station. However, in 1985, improved test equipment was procured external to the CAPS project and plans were modified accordingly. The cost of securing software for the new HP 3065 was significantly less than for the HP 3060. Also, the tests developed on the new tester are capable of handling LSI and VLSI (Large Scale Integration and Very Large Scale Integration) components such as logic, memory, and microprocessor IC's (Integrated Circuits).

The original plans also called for developing the software "in-house" and procuring the fixtures from an outside vendor, with some in-house assembly required for the fixture. Manpower obligations elsewhere precluded this approach. Instead, quotes were requested from several outside development facilities for purchase of both fixtures and software for the eight PWB Assemblies. Based on cost and firsthand knowledge of the test equipment, Hewlett-Packard was chosen to meet our requirements. A listing of the eight PWB Assemblies involved and the conversion implementation status is shown in Figure 3-3-2.

In addition to decreased time for defect identification, a number of other benefits are realized for those boards tested on the HP 3065. Since the Automated Test Station has a communication link with the VAX computer, information on defects is uploaded to facilitate the utilization of the CAPS Computer Aided Repair workstation (see Section 3.4). Since these defects are stored electronically, defect trend analyses can be developed in whatever format deemed appropriate to identify potential areas for corrective action. Also, the detailed

Figure 3-3-1 Auto Test Fixture

CAPS ATE TEST FIXTURE
IMPLEMENTATION STATUS

PWB Assembly	Sent To HP	Received From HP	Verification PWO #	Verification Date	Initial PWO #	Run Date
EA MUX 151936-0001	08/05/85	10/07/85	PH1301	11/14/85	PH0198	11/21/85
Bite 137597-0002	08/05/85	10/07/85	PH0204	11/21/85	PH1714	12/11/85
AC ALU 138204-0001	08/05/85	10/07/85	PH1065	12/04/85	PH0273	12/16/85
Ext I/O 137426-0004	08/05/85	10/07/85	PH1461	01/09/86	PH1462	03/13/86
Pwr Supply 146898-0001	08/05/85	11/26/85	PH0543	02/03/86	PH2175	02/19/86
2K RAM 146828-0002	10/31/85	01/15/86	PH1263	08/01/86	PH1254	10/16/86
Mtr Driver 146837-0001	12/11/85	02/19/86	PH1614	03/14/86	PH1615	03/14/86
Para Peripheral 151787-0001	01/30/86	03/19/86	PH1985	10/30/86		

Figure 3-3-2

Figure 3-3-3 Auto Test Workstation With Computer Aided Repair Terminal

information provided about the defect may yield clues as to the source of the problem. For example, if a component is found to be consistently on the high end of a tolerance, then the components in stock may be mismarked.

Although this part of the CAPS project deals with only eight PWB Assemblies, many future boards will also be set up to be tested on the new HP 3065 tester. Auto Test software for most of these new boards will be developed in-house; however, if the required schedule for completion of this software should exceed the available manpower, the use of outside contractors as been proven to be a viable alternative.

3.4 PWB Assembly Repair

Automated Test Equipment will usually identify faults on a PWB Assembly at the component or trace level of detail. The diagnostic printout produced tells what is defective, but not where it is on the board. Since the defect must be marked for eventual repair, the test technician must search the board to locate the trouble spot and apply the adhesive defect sticker. This locating task can be quite time consuming in the case of large boards and even more significant when pinpointing trace defects. Also, providing the part number information for component replacement means additional time searching through the Parts List documentation. The objective of the Computer Aided Repair (CAR) portion of the CAPS project was to utilize computer technology to aid in the defect location aspect of the PWB Assembly repair process.

Design data from the CAD facility and material data from TMCS are downloaded to the VAX computer and are reformatted into a form compatible with all CAPS applications. Software was developed on the VAX to produce a graphics image of the board on a high resolution SEIKO GR1104 color terminal. The process of locating the particular trace or component is

accomplished through highlighting the specific trace or the outline of the component. For those PWB Assemblies tested on the HP 3065, a communication link is established with the VAX computer so that a list of failure details can be displayed when the specific serial number of the board is input. Another feature, the labeling of all components on the screen with reference designators, will assist in situations where the identity of the components connected to a particular trace is needed. For components which are highlighted, material information is displayed to assist in the ordering of replacement parts. The process flow diagram for the utilization of the CAR workstation is shown in Figure 3-4-1. Details on the exact procedure for the process are defined in the Software Documentation Section in Appendix I of this proposal.

Development of the CAR software and associated communication links yield benefits beyond the immediate application of repair of PWB Assemblies. CAR was developed to be compatible with Tektronix 4014 so that a wide variety of terminals could be utilized. In fact, the Manufacturing Engineers have access to the CAR image on their DEC VT240 terminals, although the low resolution, monochrome display is useful only as a reference. Any future applications which need a graphic representation of the board could use this utility simply by connecting a Tektronix 4014 compatible terminal to a communication port on the VAX computer. Also, the communication links established between the VAX, CAD, TMCS, and the HP 3065 Auto Test equipment facilitates more rapid in-house development of Auto Test software for new PWB Assemblies.

3.5 PWB Identification

Several methods were investigated as possible alternatives to the manual operation of marking information onto printed wiring boards. The initial idea of modifying a computer-based plotter device encountered problems due to the difficulty

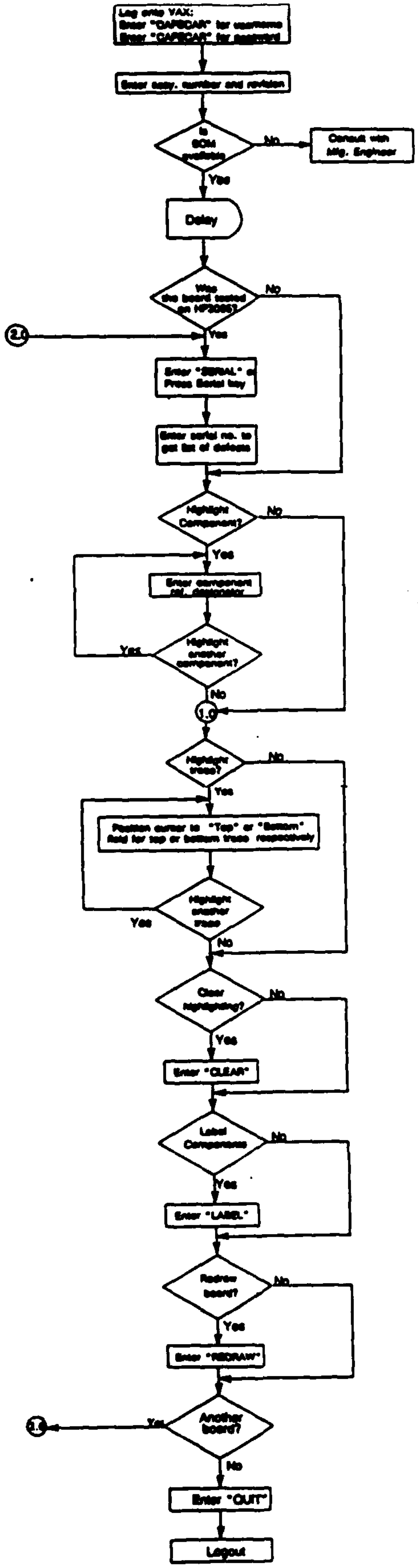


Figure 3-4-1 Computer Aided Repair (CAR) Process

of the modification and the need to develop an ink delivery device capable of applying the thick ink precisely with no damage to the traces on the board. The savings of such a system would be limited since an operator would still have to prepare the special ink, clean the delivery system, and load each board onto and off of the device.

Another alternative investigated was the utilization of a laser device to etch the information onto the board. Three problems were found with this approach which discouraged its adoption. First, a white area would have to be silkscreened onto the board in order to get the proper contrast between the alphanumerics and the background. Second, since the laser essentially "burns" the characters into board, the potential exists for damaging the traces on a board. Third, the cost of a typical system was found to be between $50K and $100K, excluding holding fixtures.

The most promising alternative appeared to be the use of special labels produced on a device which prints, laminates, and applies the label to a board placed beneath it. The label material is made of a polyimide compound with a pressure-sensitive acrylic adhesive and a polyimide-based, ink-receptive coating covered by a Kapton laminate which withstands the wave soldering and solvent cleaning environment. The printer-applicator device is computer-based and is capable of communicating with the VAX computer so that the serial numbers printed on the labels can be recorded and printed on the serial log on the back of the PWO document.

Further research into the label alternative uncovered problems that, while not insurmountable, would have resulted in a significant increase in the cost of its development. Although the special labels are widely used in commercial applications, they would have to be subjected to extensive environmental tests to meet the military standard

qualifications of the PWB Assemblies to which they are affixed. The estimated cost of conducting such tests is shown in Figure 3-5-1. Another large cost would be incurred for the process of incorporating the proposed label into the official documentation. Engineering Change Orders would have to be initiated to modify design and manufacturing documents for over 300 PWB Assemblies. Because of these costs and the costs of the capital and labor directly associated with the development of the workstation (see the CAPS SERIALIZATION WORKSTATION ANALYSIS, Figure 3-5-2), this portion of the CAPS project was identified as unattractive for further development.

3.6 Possible Future Enhancements

The development of the applications within the CAPS project and the associated effort to integrate the various computer systems and islands of automation suggested additional benefits beyond the immediate scope of this project. While these future enhancement possibilities are intangible for the cost-benefit analysis of the present project, they are an important and sometimes crucial prerequisite to implementing future manufacturing improvements.

The material and design data stored on-line in the VAX computer is readily accessible for computer-generated programming of future automated systems such as those for masking, material handling, and robotics, as well as other intelligent systems currently in-house such as the AAC Component Locator and the Component Verifier on the Sequencer. Software could be developed to automatically reorder replacement parts for those boards tested on the HP 3065 by accessing the test results and the material data associated with the particular board. In addition, the Component Data file maintained on the VAX to define the physical dimensions of the axial lead components could be expanded to include all components and could serve as reference to the Design Engineering, Incoming Inspection, and Procurement.

ENVIRONMENTAL TESTS COST FOR SERIALIZATION LABELS (PER MIL SPEC 810C)

1.	Temperature/Altitude Test:					
		Engr. Hrs.	= 6	=	$	260
		Tech. Hrs.	= 50	=	$	1,058
2.	Humidity Test:					
		Engr. Hrs.	= 10	=	$	434
		Tech. Hrs.	= 125	=	$	2,645
3.	Salt Fog Test:					
		Engr. Hrs.	= 3	=	$	130
		Tech. Hrs.	= 16	=	$	339
4.	Vibration Test:					
		Engr. Hrs.	= 166	=	$	7,205
		Tech. Hrs.	= 400	=	$	8,464
		Fixture Material		=	$	750
5.	Fungus Test:					
		Engr. Hrs.	= 32	=	$	1,389
		Outside Vendor		=	$	600
		Travel		=	$	2,000
6.	Test Report:					
		Engr. Hrs.	= 50	=	$	2,170
		TOTAL COST:				
			LABOR	=	$	24,094
			OTHER	=	$	3,350

Figure 3-5-1

CAPS
SERIALIZATION WORKSTATION ANALYSIS

COST:

Equipment -			
o Automated Label Maker/Applicator		$	20K
o Bar Code Reader and VAX Link		$	5K
Qualification Test -			
o Environmental Test to meet MIL STD 810C		$	27.4K
Development Labor -			
o Computer Programmer	160 hrs	$	4.6K
o Project Investigator	80 hrs	$	3.1K
o Mfg. Engineer	160 hrs	$	6.3K
o Quality Engineer	160 hrs	$	5.1K
o Quality Control	200 hrs	$	4.4K
	SUBTOTAL	$	23.5K
Incorporate ECO's -			
o 300 ECO's X $500 per ECO*		$	150.0K
Net Material Costs -			
	GRAND TOTAL COSTS	$	225.9K
		+	1 K/yr

BENEFIT:

7634 hrs over 7 years = $ 183,290 = $ 26,184/yr

* = Conservative Estimate

Figure 3-5-2

Various types of analyses can be performed using the data captured or stored on the VAX computer. CAD data could be analyzed for manufacturability. Data captured from Auto Test could be analyzed to determine any defect trend patterns. In addition, Method Codes could be analyzed relative to production volumes to identify possible bottlenecks in the process flow.

The Method Code system (three letter codes representing a task and its corresponding time) uses only a fraction of its total capacity. The "A__", "B__", and "Q__" series codes are reserved for PWB Assembly instruction sheet generation. Over 15,000 codes are available for use in other applications such as instruction sheet generation in other manufacturing areas, flow chart generation, and inspection defect codes. Use of the Method Code system in these areas would allow electronic access to the data for display and computer analysis. When used to define predetermined tasks and times for an Instruction Sheet, the method code system will facilitate compliance with MIL-STD 1567A.

The CAPS Instruction Sheet Generator still requires inputs from a qualified Manufacturing Engineer with knowledge of the manufacturing environment and the requirements of the product design. Since CAPS has access to the design information, the next logical evolution of the Instruction Sheet Generator is for the computer to anticipate the correct Method Code to be input, based on the design data and a set of manufacturing environment "rules" which artifically reflect the intelligence and thought patterns of the M.E. Such a system would further reduce the time involved in producing instructions and would preserve the knowledge of proper manufacturing techniques.

Another improvement facilitated by CAPS is the possibility of "paperless" instructions. The instructions would be available electronically to manufacturing personnel via video

terminals. Any changes to the information could be put into effect as soon as the M.E. made the revision. Also, since the M.E. can view both the completed instruction sheet and a drawing with CAPS, the technology exists for expanding the capability to the manufacturing area, although the cost of the expansion is currently prohibitive. Installation of additional CAR terminals may be feasible in some manufacturing areas with very little additional software development required.

4.0 PROJECT ASSUMPTIONS

Some of the benefits of CAPS, although tangible, cannot be expressed in terms of direct labor "time per board" savings. Specifically, the unit of measure for generation of instruction sheets and input of bill of labor is "time per instruction sheet". Likewise, the unit of measure for generation of component insertion programs and development of test programs is "time per program". To calculate savings, each of these three types of unit of measure must be multiplied by the corresponding type of volume (for example, time per instruction sheet X number of instruction sheets). The format of the savings calculations require that the volume be defined over time and customer category. Two of the three types of volumes, the number of instruction sheets and the number of insertion programs, cannot be readily defined in terms of time and customer category. Therefore, for savings calculations, an assumption was made that volumes for those two types have a direct correlation with the board production volume in regards to distribution over time and distribution over customer category. For example, assume that 10 insertion programs were written in 1986 and the 1986 board production volume was 25,000 boards. If the projected production board volume for 1987 was 50,000 boards, then the projected volume of insertion programs would be 20. The same apportioning methodology would be used for all appropriate years and customer categories. The rationale for this assumption is that the low volume/high product mix environment of this production area and the generally short life electronic designs (i.e., frequent redesigns) is an effective indicator of overall activity.

5.0 COST

See Volume II.

6.0 SAVINGS ANALYSIS PROCEDURE

The numerous features encompassed within the CAPS project have a significant impact on the Printed Wiring Board production process. The thirteen cost drivers chosen for the cost benefit analysis were selected on the basis of their ability to be quantified using auditable and rational data. Intangible benefits, such as compliance to military standards and providing the foundation for future improvements, are not included. Also, the increase in productivity due to fewer errors was not included due to the ambiguous format of the data which could not clearly segregate the effect of the project. All but four of the cost driver incremental times (time per unit of measure) were based, directly or indirectly, on Industrial Engineering stopwatch time studies. Touch labor actuals and an engineering projection were used for the remaining cost drivers.

Each cost driver incremental time is quantified on an annual basis for the years in which it would be in effect. The methodology for quantifying the cost driver times annually differs depending on the nature of the cost driver. In general, for those cost drivers whose unit of measure volume cannot be discerned directly for all relevant years, the unit of measure volume for the current year is projected for the remaining years and apportioned over the customer categories based on a direct correlation with the production Build Schedules (refer to 4.0 Project Assumptions).

Instant, or Firm-Planned, Build Schedules were extracted by computer software from the Customer Order Book in Operations Services, Manufacturing Division, in October 1986. The Customer Order Book is the official record of Tracor delivery schedules, and drives all manufacturing activities. It is kept up-to-date by technicians based on inputs from Contracts Division through and in conjunction with, the respective Program Managers. The Instant Build Schedule contains "deliverable" part

numbers, project numbers, quantities, and dates. Since the project number refers to the customer, it was a simple matter to divide up the project number into one of four customer categories:

1 - F-16 (General Dynamics, Ft. Worth)
2 - USAF
3 - DoD (other than USAF)
4 - Commerical

This was done, and the result was an Instant Build Schedule for all four customer categories showing "deliverable" part numbers, quantities, and years (1986-1993).

Follow-On Build Schedules were extracted from the Business Development Bookings Forecast. This document is updated monthly by the Business Development Division, based on inputs from the program managers. It contains system identifiers, delivery dates, customer information, etc. For Tech Mod's purposes a separate file was set up to tie the system identifiers to existing LRU's, where possible. Where this was not possible, the system identifiers were sometimes tied to "representative" LRUs, i.e., an LRU that would be roughly equivalent in terms of the manufacturing resources required. In some cases the bookings forecast could not be defined in terms of manufacturing hours required.

The Booking Forecast as presently structured has four customer codes. They are:

C - Commercial	- Non-military domestic sales
G - Government	- U.S. Government sales where the intended use is the U.S. Government
F - Foreign	- Foreign Military Sales (FMS). Sales initiated through a U.S. Government procurement activity where the intended use is the foreign government
I - International	- Direct foreign sales of any product

By combining the Government (G) and Foreign (F) categories a build schedule entitled "Government" was created; by combining the Commercial (C) and International (I) categories a build schedule entitled "Commercial" was created.

The computer was programmed to look at all bookings, determine the LRU's (based on the system identifier) and multiply the probability of capture by the gross quantities shown. It then printed out the build schedules showing the LRU's and the year in which they would be built.

Two adjustments were made to the Follow-On Build Schedule numbers. To negate the "trailing off" effect of the Bookings Forecast, a straight-line production rate was substituted for the Government and Commercial numbers for the years 1990 through 1993 inclusive, based on the average of years 1988 and 1989. The second adjustment distributes the Government category numbers over the categories of F16, USAF, and DoD. This distribution is based on the ratio of the totals of each of the three categories to their sum in the Instant Build Schedule.

It should be noted that six of the thirteen cost drivers will not be included in the ITM Discounted Cash Flow Model. Four of these six cost drivers are associated with the input of the Bill of Labor by Document Control personnel who are classified as overhead. The other two cost drivers are associated with the generation of manufacturing packages by Manufacturing Engineers who charge time to Production Support Accounts (PSA). Therefore, savings for these cost drivers would be difficult to identify and validate.

6.1 PWB Assembly Instructions

The computer-assisted generation of detailed PWB assembly instructions has a beneficial effect on eight cost drivers. The production of the instruction sheets, themselves,

by the manufacturing engineers takes less time even though the amount of information provided has dramatically increased. Time Studies were performed on the "AS-IS" and "TO-BE" methods used to produce completely "new" instruction sheets using a typical size assembly. In the case of "revised" (rather than "new") instruction sheets the M.E. will also save time depending on the no of changes to be made and how many instruction sheets are changed per year. Projections were used for the time required to revise instructions. These projections were based on the above study, assuming an average of three operations changed per revision, using the formula:

$$\frac{\text{total time/instruction sheet}}{\text{number of operations}} \times \text{average of 3 operations/revision}$$

"AS-IS" and "TO-BE" times were recorded per instruction sheet. To determine the annual volume of instruction sheets written using CAPS, a count of new instruction sheets on file electronically was made. For the nine months between January 1986 and September 1986, 119 instruction sheets were produced - an average of 159 per year. Although not all new instruction sheets are processed by Document Control, all revisions to instruction sheets are. The number of revised instruction sheets was derived from records kept by Document Control for the months between February 1986 and August 1986 excluding April 1986. The savings calculations have been adjusted to reflect anticipated completion of development.

Bill of Labor time standards are determined by the M.E. for each operation on an instruction sheet. This information is input to TMCS on the mainframe computer. With the CAPS system, the information is uploaded electronically for both the PWB Assembly instruction sheets produced using CAPS and the Fab Shop instruction sheets produced outside of CAPS. The only remaining labor associated with the "TO-BE" upload procedure is the input of the appropriate assembly or fab number by Document

Control to formally initiate the procedure. There are four different types of inputs involved in this input procedure - new and revised Bills of Labor for PWB Assembly and Fab. The revised Bill of Labor input requires more time for the "AS-IS" procedure due to the necessity of searching the instruction sheet to locate the revisions. The input of Fab Bills of Labor require less time than that for PWB Assemblies because of the fewer number of operations. Three of the four types of inputs were time studied. The time for the remaining type, input of a new FAB Bill of Labor, was projected using the following formula:

$$\frac{\text{time for input of FAB revision}}{\text{time for input of PWBA revision}} \times \text{time for input of new PWBA}$$

As in the time calculations for producing instruction sheets, the unit of measure for input of the Bill of Labor is "time per instruction sheet." The unit of measure volumes associated with the four types of input procedures were derived from records kept by Document Control for the months between February 1986 and August 1986 excluding April 1986. The savings calculations have been adjusted to reflect the May 1986 completion date.

The majority of the savings associated with the instruction sheet generator portion of the CAPS project is attributed to increased information supplied to manufacturing via the detailed instruction sheet. This portion of the project was the first to be developed and, from the standpoint of touch labor, should be considered fully operational and installed as of January 1986. The year 1985 should be considered a transitional development period, and the year 1984 would be considered the prior period, i.e., before the beneficial effect from the CAPS instruction sheets. With these time frames in mind, a computer analysis of historical touch labor actual charges was produced for a sample group of PWB assemblies to demonstrate the savings per part between the "AS-IS" year (1984) actuals and the "TO-BE" (1986) year-to-date (as of September 1, 1986) actuals. The

resulting average savings was then spread over the adjusted production volumes for the appropriate customer categories and affected years.

6.2 Auto Component Insertion Programming

The methodology for calculating savings for this portion of the CAPS project is based on time studies normalized for the average number of components inserted per board, and the number of auto insertable assemblies on file divided by the number of years the auto insertion equipment has been available. The "AS-IS" time was studied separately for the VCD and the DIP machines since the latter is more difficult to program. The time for each was multiplied by the average number of insertable components per assembly (55 for the VCD; 21 for the DIP) as derived from an analysis of the associated method code defined by the CAPS instruction sheet files. The CAPS method code analysis software is a feature of CAPS which searches for the number of occurrances of a specified method (code), as defined by the manufacturing engineer, in the instruction sheet generator input sheet for all electronically stored files on CAPS. The calculation of the "TO-BE" times for the VCD and DIP machines allows for both a constant value (time to initiate the program generator, regardless of the number of components) and a varible value (to verify the correct location of each component).

For the "TO-BE" method, the formula is:
(average number of components inserted
X time to verify correct location)
\+ time to initiate the program generator

The two time values in the above formula are the same for both the VCD and DIP machines. The unit of measure volume is in terms of number of programs generated per year. This figure is calculated by the number of auto insertable assemblies on file divided by the seven years the equipment has been in use. The

resulting average savings is then spread over the adjusted production volumes for the appropriate customer categories and affected years, with the 1986 savings adjusted to reflect the anticipated completion date.

6.3 PWB Assembly Testing

The savings for this portion of the CAPS project is limited to eight specific PWB Assemblies which were targeted for development on the new HP 3065 Auto Test equipment. Development was completed in March of 1986. Computer analysis of historical touch labor actuals is presently available for only six of the eight PWBA's. The average savings for the six was calculated and applied to the anticipated volume for all eight PWBA's, with the 1986 savings adjusted to reflect the completion date.

6.4 PWB Assembly Repair

As in the PWB Assembly Testing portion of CAPS, the savings associated with the CAR workstation is limited to specific thirteen PWBA's, although future yet-to-be developed PWBA's could be tested on the HP 3065. Industrial Engineering time studies were used to determine the typical "As-Is" and "To-Be" times. The savings was applied to the anticipated volume for the thirteen PWBA's, with the 1986 savings adjusted to reflect the anticipated completion date.

COST-BENEFIT ANALYSIS METHODOLOGY

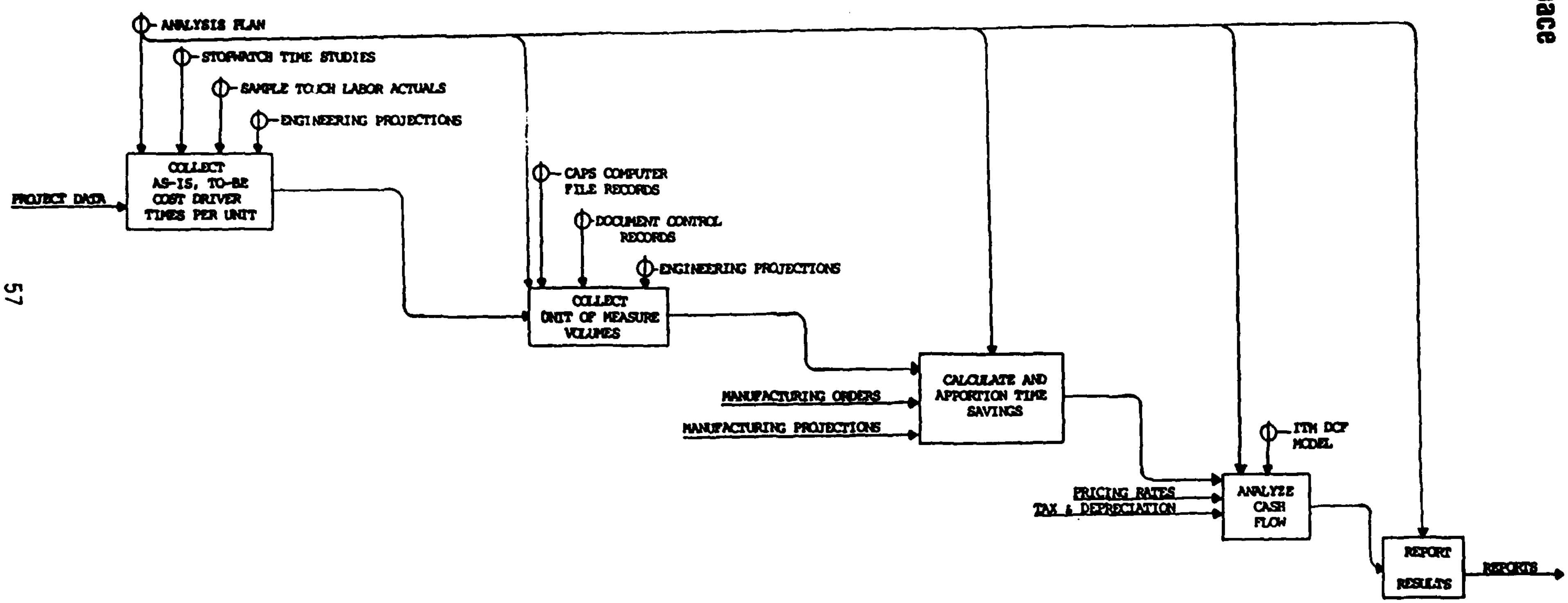


Figure 6-3

7.0 SAVINGS VALIDATION

The "TO-BE" incremental times, the units of measure volumes (where applicable), and the production build schedules will be validated within 18 months from the date of implementation. The methodology will be the same as used in the Saving Analysis Procedure (see Section 6.0) with two exceptions.

The processes of PWB Assembly Test and PWB Assembly Repair are difficult to distinguish from one another in the real world environment. Although separate labor charge numbers exist for test and for repair, some identification for repair occurs during the test process. Therefore, after implementation, the effect of the CAR workstation on actual touch labor charges will be indistinguishable from the effect of the improved test procedure.

In order to validate the savings for the eight PWB Assemblies for which CAPS affected both the test and repair processes, touch labor actuals for the time prior to implementation of either new process will be compared to touch labor actuals after implementation of both new processes. The results, although not itemized separately, will reflect the total effect of both parts of the CAPS project.

For those assemblies whose test fixture/software development were not within the scope of CAPS, time studies will be used to demonstrate the CAR savings. The magnitude of the savings will likely be less than shown in this proposal, however, since the savings for eight of the PWB Assemblies affected by CAR has already been accounted for in the savings associated with the Auto Test development portion of CAPS, as explained in the previous paragraph. Production build schedules for all cost drivers, including CAR and Auto Test, will be updated.

VOLUME I

ATTACHMENTS

TABLE 1

PROJECT ECONOMIC SUMMARY

COMPUTER AIDED PROCESSING SYSTEM (CAPS)

FINAL TECHNICAL REPORT

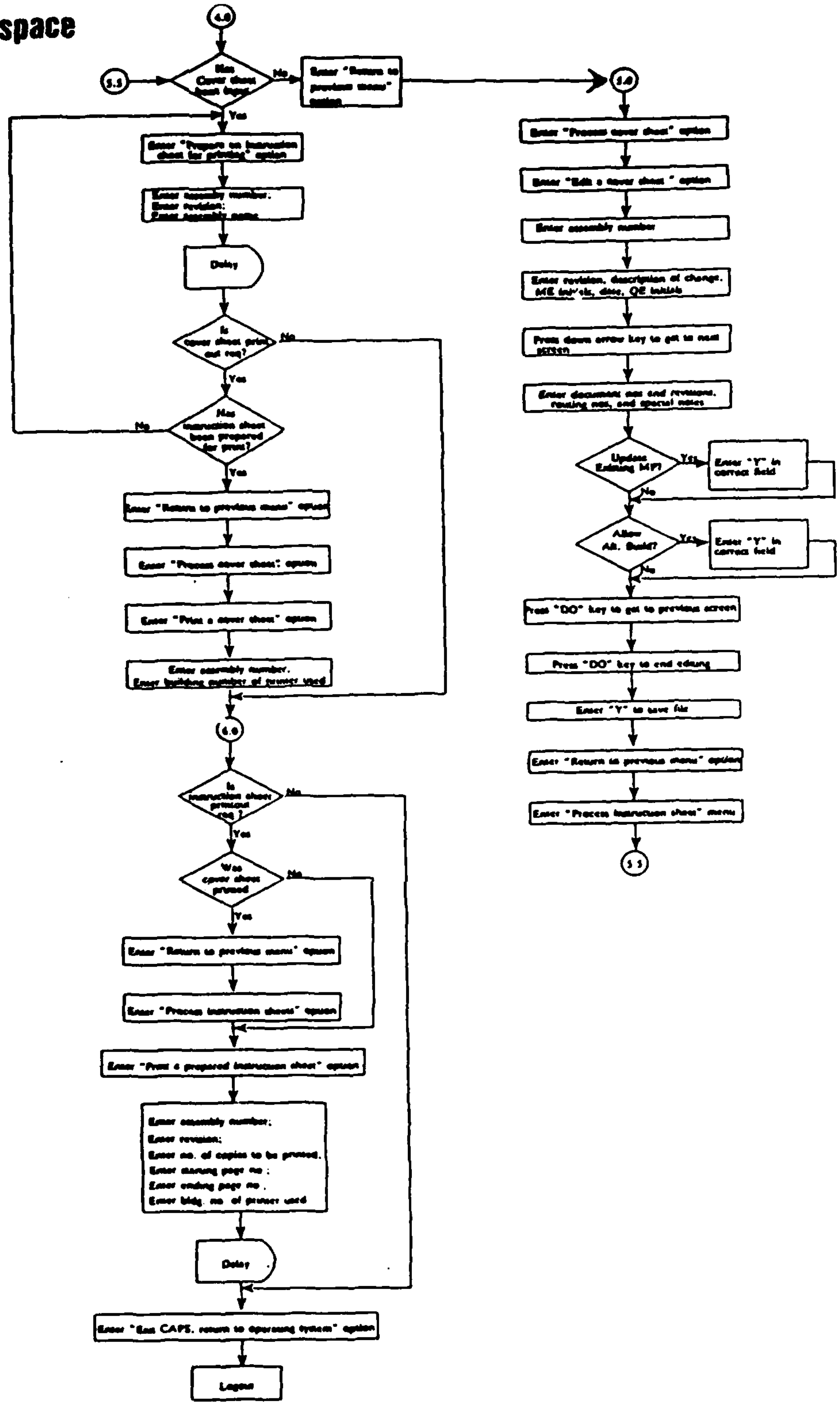
Implementation Date:		Jan. and Oct. 1986
Manhour Savings:	F-16 Instant	30.2
	F-16 Future	23.8
	Other DoD Instant	11,751.1
	Other DoD Future	9,665.9
	TOTAL	21,471.0
Material and Labor Savings:	F-16 Instant	$ 693
	F-16 Future	$ 706
	Other DoD Instant	$ 282,971
	Other DoD Future	$ 306,314
	TOTAL	$ 590,683
Internal Rate of Return:		35.0%
DoD To Total Production Ratio:		0.80
Subcontrator Capital Expenditures:		$ 214,492
Subcontractor Related Funds:		$ 54,745
DoD Funds:		$ 54,320
Productivity Savings Reward (PSR):		$ 283,664

COMPUTER AIDED PROCESSING SYSTEM (CAPS)

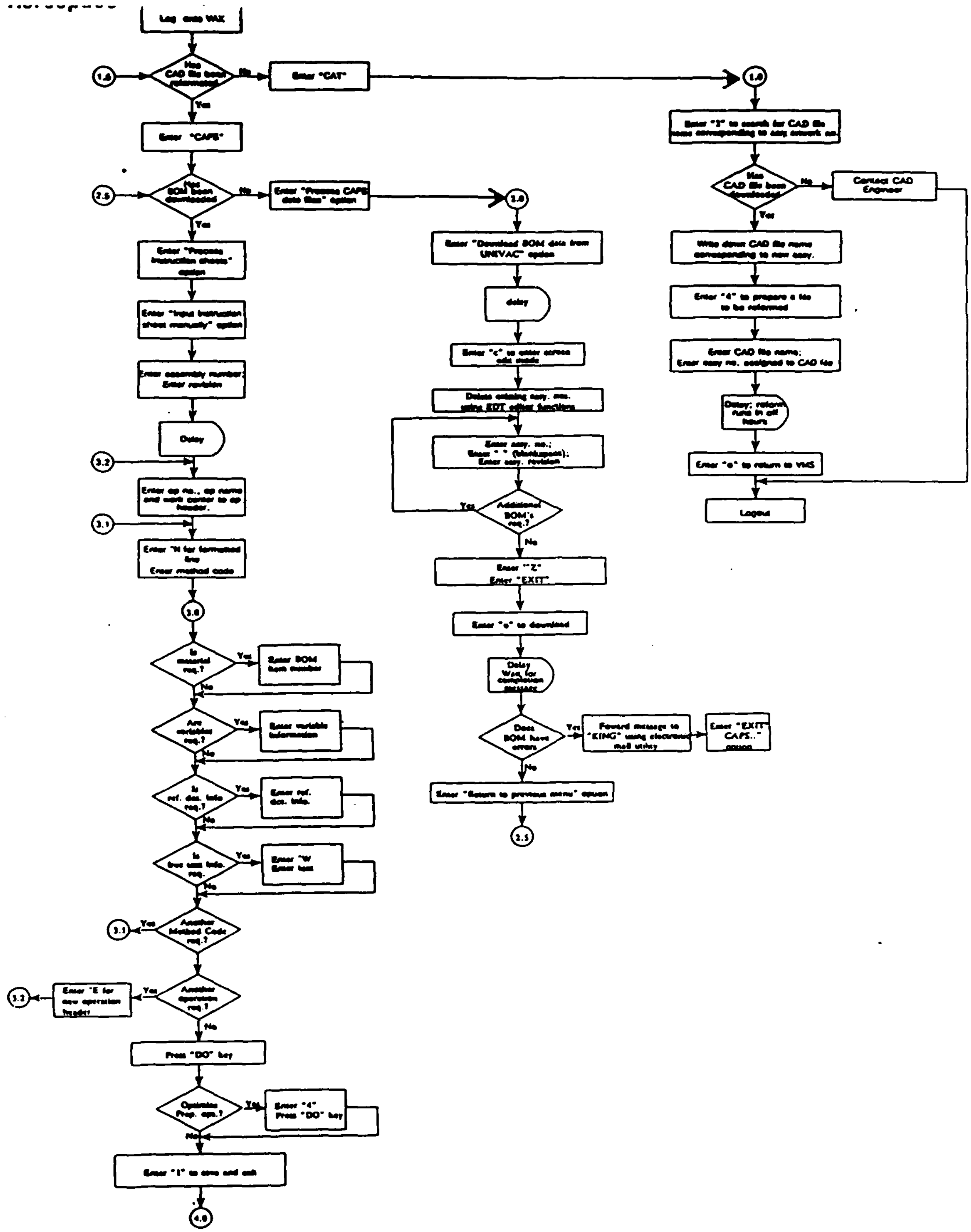
FINAL TECHNICAL REPORT

ATTACHMENT A - "AS-IS" AND "TO-BE" PROCESS FLOWCHARTS

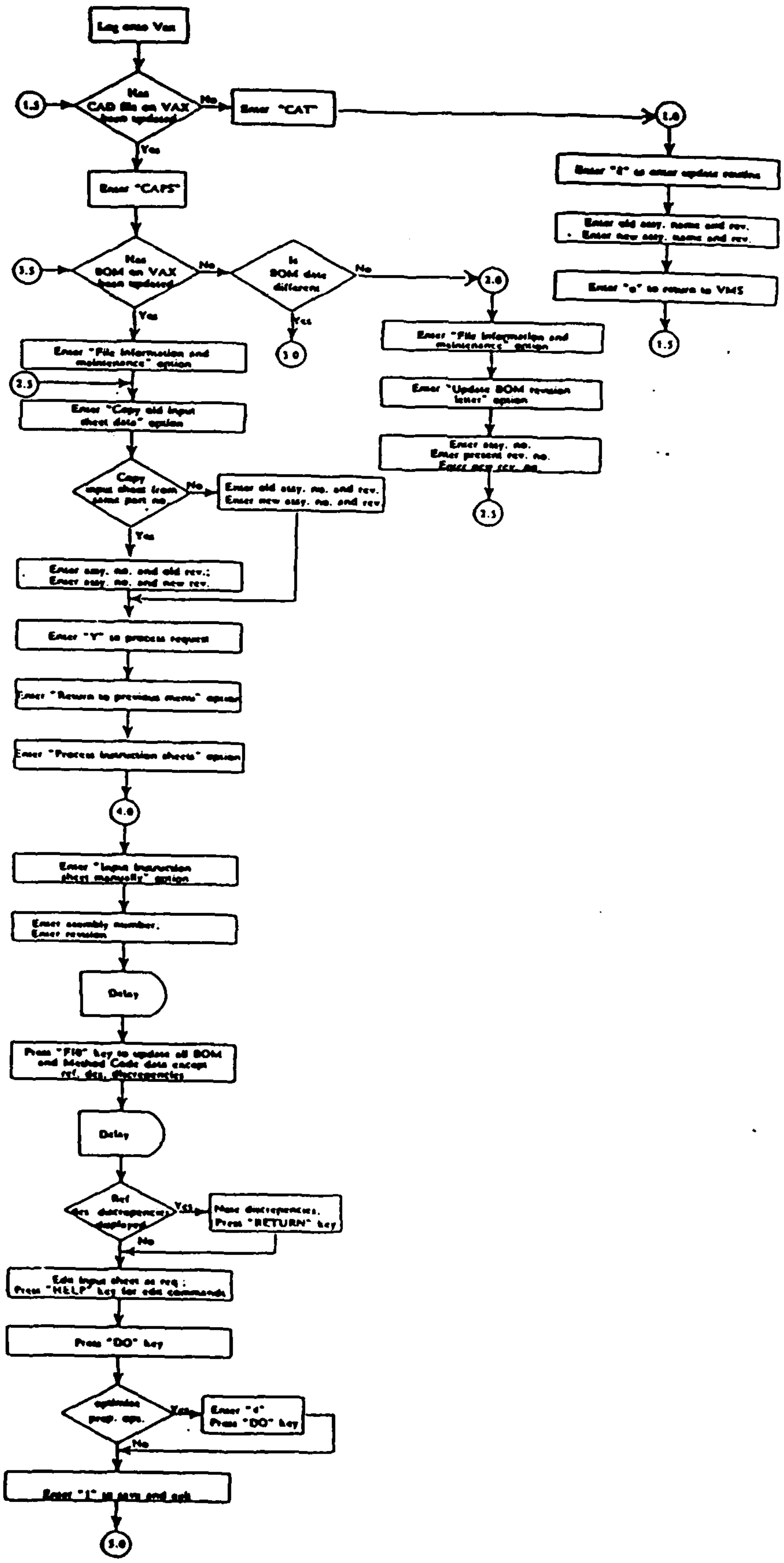
See the following eight pages.



Write An Instruction Sheet Using CAPS

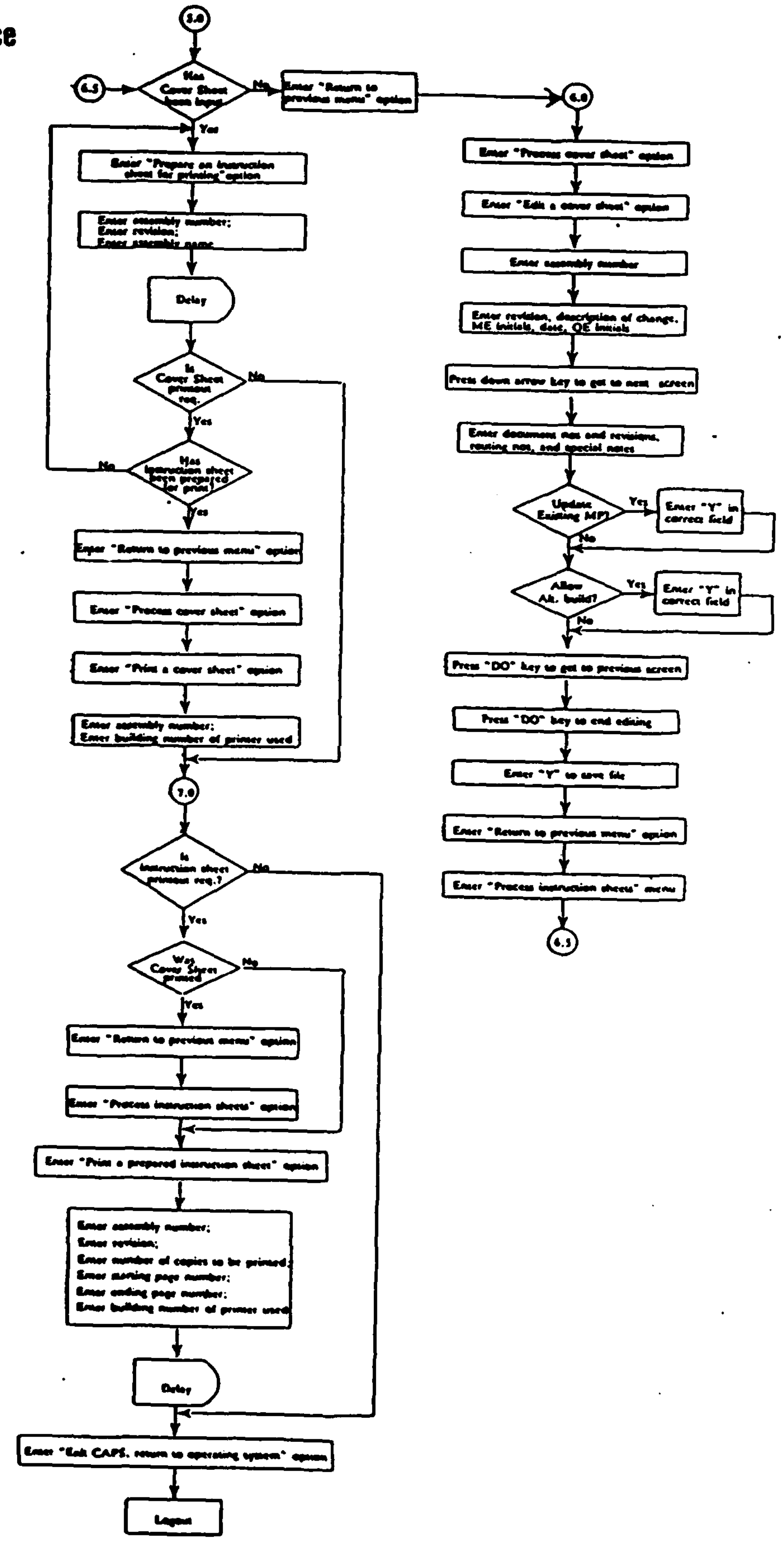


Write An Instruction Sheet Using CAPS (cont.)

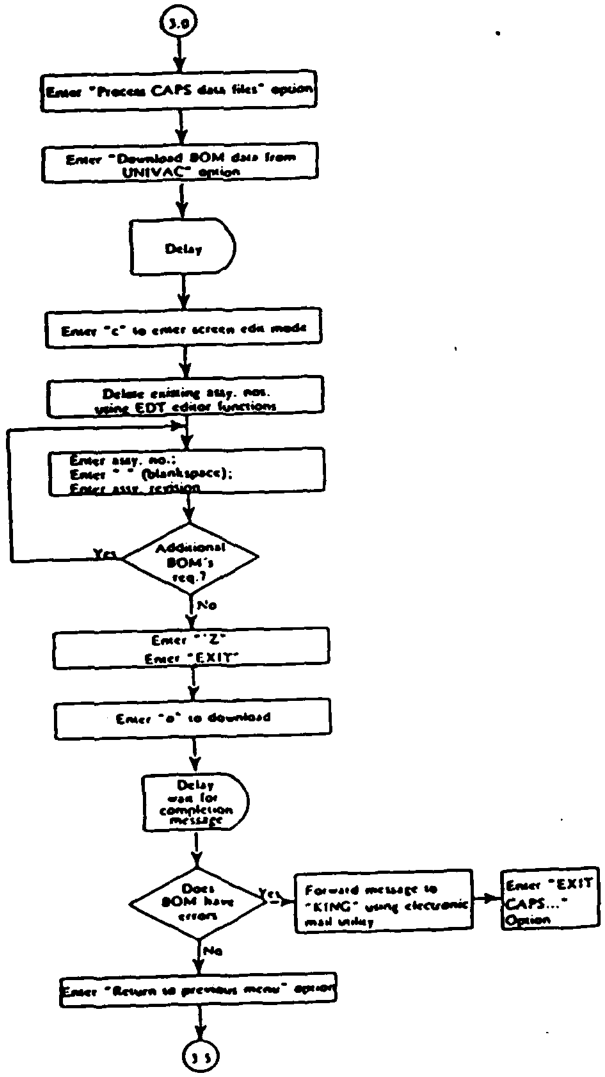


Revise An Instruction Sheet Using CAPS

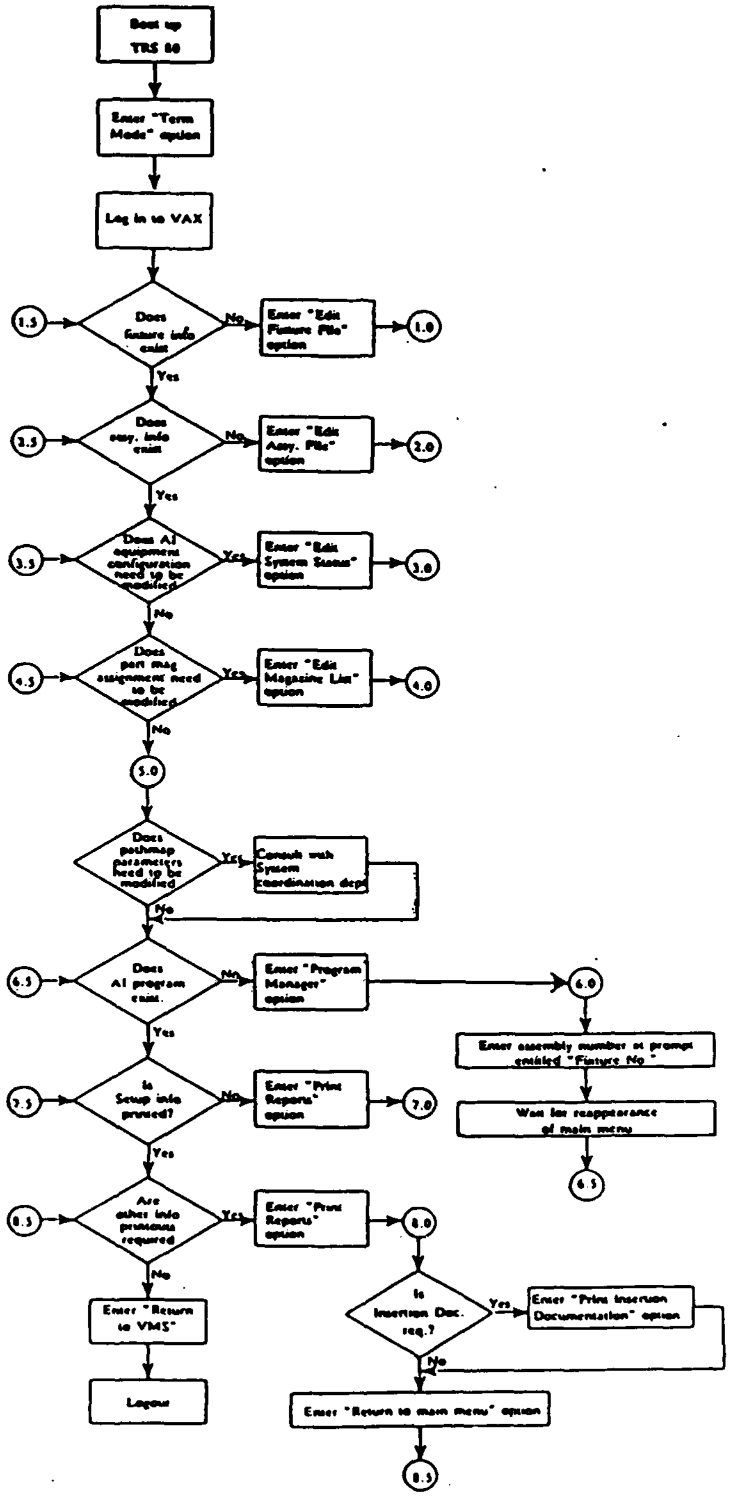
Tracor Aerospace



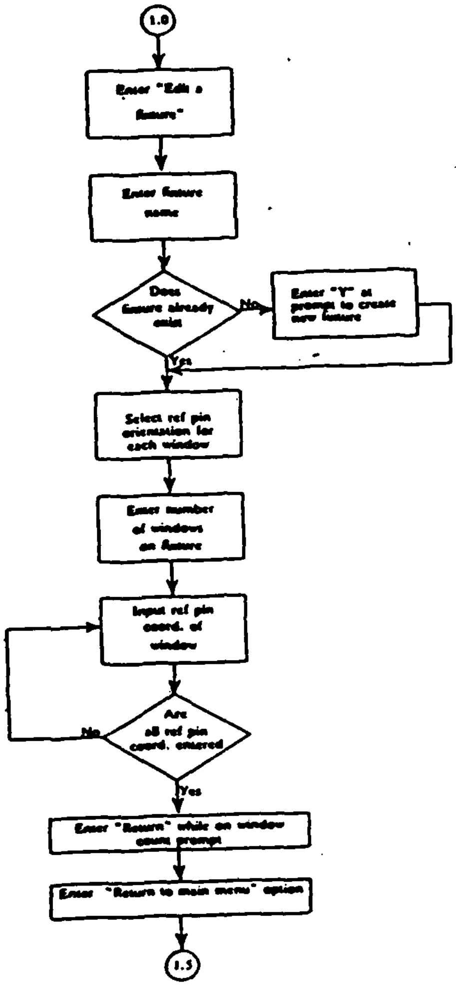
Revise An Instruction Sheet Using CAPS (cont.)



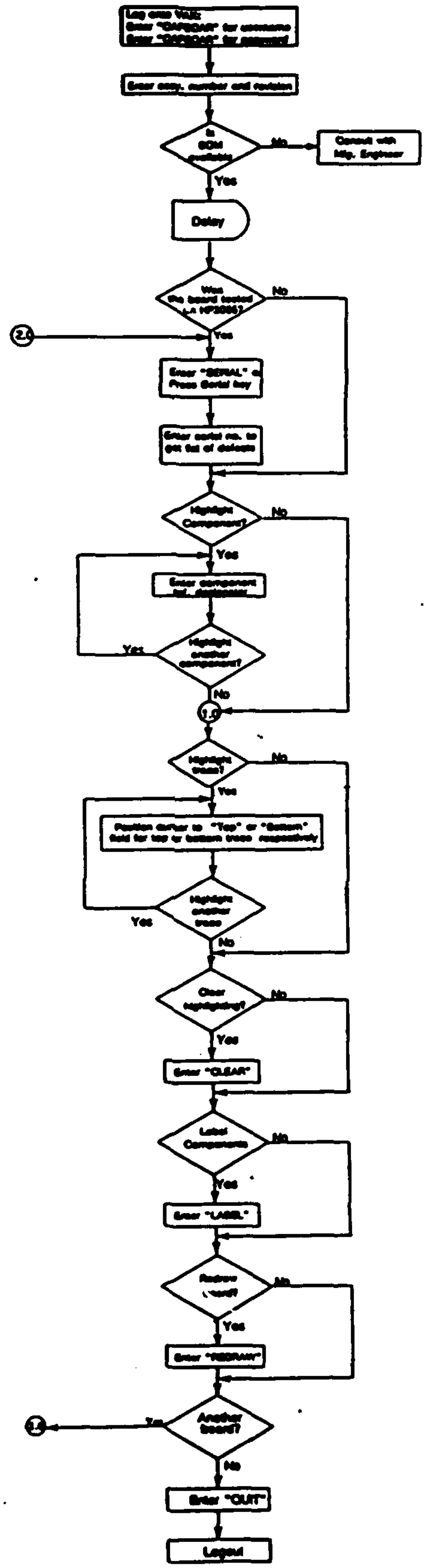
Revise An Instruction Sheet Using CAPS (cont.)



Generate Component Inserter Program Using CAPS



Generate Component Inserter Program Using CAPS (cont.)



Computer Aided Repair (CAR) Process

COMPUTER AIDED PROCESSING SYSTEM (CAPS)

FINAL TECHNICAL REPORT

ATTACHMENT B - CAPITAL EXPENDITURE SUMMARY

Description	1984	1985	Implementation Date
DIP Component Verifier	$ 21,495		1986
Axial Component Verifier	$ 38,055		1986
Computer CPU, Disk, Tape, Console Software & Manuals	$ 86,592		1986
Auto Switchbox	$ 622		1986
Cables	$ 507		1986
Connector Hardware	$ 323		1986
Two Switchboxes	$ 530		1986
Sightscreens	$ 1,376		1986
Two Modems	$ 700		1986
Three Terminal	$ 5,340		1986
Two Modems	$ 1,050		1986
Graphics Terminal	$ 4,750		1986
Eight Test Fixtures		$ 16,650	1986
Microcomputer (CAD Comm. Link)		$ 2,700	1986
Auto Switchbox (CAD Comm. Link)		$ 847	1986
Connector Hardware (CAD Comm. Link)		$ 65	1986
SUBTOTAL	$161,340	$ 20,262	
Sales Tax ('84 .05125, '85 .06125)	$ 8,269	$ 1,241	
Mtl OH ('84 .1236, '85 .1124)	$ 20,964	$ 2,417	
TOTAL CAPITAL	$190,572	$ 23,920	
CUM CAPITAL	$190,572	$214,492	

COMPUTER AIDED PROCESSING SYSTEM (CAPS)
FINAL TECHNICAL REPORT
ATTACHMENT C - MANUFACTURING SCHEDULE - ALL PWB ASSEMBLIES

CATEGORY/YEAR		1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
SCHED VOLUME:										
INSTANT:	F-16	148	168							316
	USAF	44269	46546	6548						97363
	DoD	7229	6407	2410						16046
	COML	1944	2705	2459	49					7157
SUBTOTAL:		53590	55826	11417	49					120882
PROPOSED:	GOVT		166	18497	11516	5097	5261	3134	830	44501
	COML		2440	4463	3650	2212	2100	720	190	15775
SUBTOTAL:			2606	22960	15166	7309	7361	3854	1020	60276
TOTAL:		53590	58432	34377	15215	7309	7361	3854	1020	181158
ADJ #1 VOLUME:										
INSTANT:	F-16	148	168							316
	USAF	44269	46546	6548						97363
	DoD	7229	6407	2410						16046
	COML	1944	2705	2459	49					7157
SUBTOTAL:		53590	55826	11417	49					120882
PROPOSED:	GOVT		166	18497	11516	19520	19520	19520	19520	108257
	COML		2440	4463	3650	5276	5276	5276	5276	31659
SUBTOTAL:			2606	22960	15166	24796	24796	24796	24796	139916
TOTAL:		53590	58432	34377	15215	24796	24796	24796	24796	260798
ADJ #2 VOLUME:										
INSTANT:	F-16	148	168							316
	USAF	44269	46546	6548						97363
	DOD	7229	6407	2410						16046
	COML	1944	2705	2459	49					7157
SUBTOTAL:		53590	55826	11417	49					120882
PROPOSED:	F-16			51	32	54	54	54	54	301
	USAF		142	15836	9859	16711	16711	16711	16711	92682
	DoD		23	2610	1625	2754	2754	2754	2754	15275
	COML		2440	4463	3650	5276	5276	5276	5276	31659
SUBTOTAL:			2606	22960	15166	24796	24796	24796	24796	139916
TOTAL:		53590	58432	34377	15215	24796	24796	24796	24796	260798

COMPUTER AIDED PROCESSING SYSTEM (CAPS)
FINAL TECHNICAL REPORT
ATTACHMENT C - MANUFACTURING SCHEDULES - AUTO TEST UTIL PWB ASSEMBLIES

CATEGORY/YEAR		1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
SCHED VOLUME:										
INSTANT:	F-16									
	USAF	4610	7736	1762						14108
	DoD	7								7
	COML									
SUBTOTAL:		4617	7736	1762						14115
PROPOSED:	GOVT			3297	896					4193
	COML									
SUBTOTAL:				3297	896					4193
TOTAL:		4617	7736	5059	896					18308
ADJ #1 VOLUME:										
INSTANT:	F-16									
	USAF	4610	7736	1762						14108
	DoD	7								7
	COML									
SUBTOTAL:		4617	7736	1762						14115
PROPOSED:	GOVT			3297	896	2978	2978	2978	2978	16103
	COML									
SUBTOTAL:				3297	896	2978	2978	2978	2978	16103
TOTAL:		4617	7736	5059	896	2978	2978	2978	2978	30218
ADJ #2 VOLUME:										
INSTANT:	F-16									
	USAF	4610	7736	1762						14108
	DoD	7								7
	COML									
SUBTOTAL:		4617	7736	1762						14115
PROPOSED:	F-16									
	USAF			3295	896	2976	2976	2976	2976	16095
	DoD			2		1	1	1	1	8
	COML									
SUBTOTAL:				3297	896	2978	2978	2978	2978	16103
TOTAL:		4617	7736	5059	896	2978	2978	2978	2978	30218

COMPUTER AIDED PROCESSING SYSTEM (CAPS)
FINAL TECHNICAL REPORT
ATTACHMENT C - MANUFACTURING SCHEDULES - CAR PWB ASSEMBLIES

CATEGORY/YEAR		1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
SCHED VOLUME:										
INSTANT:	F-16									
	USAF	5855	9312	1762						16929
	DoD	118	176	142						436
	COML		599	44						643
SUBTOTAL:		5973	10087	1948						18008
PROPOSED:	GOVT			3552	1087	132	148	66		4985
	COML			11	4					15
SUBTOTAL:				3563	1091	132	148	66		5000
TOTAL:		5973	10087	5511	1091	132	148	66		23008
ADJ #1 VOLUME:										
INSTANT:	F-16									
	USAF	5855	9312	1762						16929
	DoD	118	176	142						436
	COML		599	44						643
SUBTOTAL:		5973	10087	1948						18008
PROPOSED:	GOVT			3552	1087	3290	3290	3290	3290	17800
	COML			11	4	11	11	11	11	58
SUBTOTAL:				3563	1091	3301	3301	3301	3301	17858
TOTAL:		5973	10087	5511	1091	3301	3301	3301	3301	35866
ADJ #2 VOLUME:										
INSTANT:	F-16									
	USAF	5855	9312	1762						16929
	DoD	118	176	142						436
	COML		599	44						643
SUBTOTAL:		5973	10087	1948						18008
PROPOSED:	F-16									
	USAF			3463	1060	3208	3208	3208	3208	17354
	DoD			89	27	83	83	83	83	447
	COML			11	4	11	11	11	11	58
SUBTOTAL:				3563	1091	3301	3301	3301	3301	17858
TOTAL:		5973	10087	5511	1091	3301	3301	3301	3301	35866

COMPUTER AIDED PROCESSING SYSTEM (CAPS)

FINAL TECHNICAL REPORT

ATTACHMENT D - PROJECT PROCESS SPREADSHEET

	1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
I. AS-IS Process									
Instruction Sheet Generator									
Produce Instruction Sheets									
New Instructions	43	280	165	73	119	119	119	99	1016
Revise Instructions	72	468	276	122	199	199	199	166	1700
Input Bill of Labor									
New Assembly-PWBA	2	3	2	1	1	1	1	1	12
New Assembly-FAB	7	13	8	3	6	6	6	2	50
Revision -PWBA	230	429	253	112	182	182	182	76	1646
Revision-FAB	310	581	342	151	247	247	247	103	2228
Manufacturing Labor									
Component Prep	9847	10737	6317	2796	4556	4556	4556	0	43365
Manual Assembly	14405	15707	9241	4090	6665	6665	6665	0	63438
Component Insertion Program Generator									
Program VCD	1	5	3	1	2	2	2	2	18
Program DIP	2	13	7	3	5	5	5	4	45
PWB Assembly Test									
HP3065 Test Brds (8 assys)	137	240	88	0	0	0	0	0	465
Test Program Development	40	262	154	68	111	111	111	93	950
PWB Assembly Repair									
HP3065 Tested Boards	11	89	33	0	0	0	0	0	134
II. TO-BE Process									
Instruction Sheet Generator									
Produce Instruction Sheets									
New Instructions	23	147	87	38	63	63	63	52	535
Revise Instructions	58	380	224	99	161	161	161	134	1379
Input Bill of Labor									
New Assembly-PWBA	0	0	0	0	0	0	0	0	0
New Assembly-FAB	0	0	0	0	0	0	0	0	0
Revision -PWBA	3	5	3	1	2	2	2	1	19
Revision-FAB	5	9	5	2	4	4	4	2	35
Manufacturing Labor									
Component Prep	7664	8357	4916	2176	3546	3546	3546	0	33751
Manual Assembly	11569	12614	7421	3284	5353	5353	5353	0	50947
Component Insertion Program Generator									
Program VCD	1	4	2	1	2	2	2	1	15
Program DIP	0	3	2	1	1	1	1	1	10
PWB Assembly Test									
HP3065 Test Brds (8 assys)	69	120	44	0	0	0	0	0	233
Test Program Development	16	105	62	27	44	44	44	37	380
PWB Assembly Repair									
HP3065 Tested Boards	5	39	14	0	0	0	0	0	58
III. Delta									
Instruction Sheet Generator									
Produce Instruction Sheets									
New Instructions	20	132	78	34	56	56	56	47	481
Revise Instructions	14	88	52	23	38	38	38	31	321
Input Bill of Labor									
New Assembly-PWBA	2	3	2	1	1	1	1	1	12
New Assembly-FAB	7	13	8	3	6	6	6	2	49
Revision -PWBA	227	424	250	110	180	180	180	75	1626
Revision-FAB	306	572	337	149	243	243	243	101	2193
Manufacturing Labor									
Component Prep	2183	2381	1401	620	1010	1010	1010	0	9615
Manual Assembly	2836	3092	1819	805	1313	1313	1313	0	12491
Component Insertion Program Generator									
Program VCD	0	1	1	0	0	0	0	0	2
Program DIP	1	9	5	2	4	4	4	3	32
PWB Assembly Test									
HP3065 Test Brds (8 assys)	177	396	259	46	0	152	152	152	1373
Test Program Development	24	157	92	41	67	67	67	56	570
PWB Assembly Repair									
HP3065 Tested Boards	21	215	118	23	70	70	70	59	647

NOTE: Values are in manhours.

COMPUTER AIDED PROCESSING SYSTEM (CAPS)

FINAL TECHNICAL REPORT

ATTACHMENT E - SAVINGS CALCULATIONS

See the following page.

ROW/COL	A		B	C	D	J	K	L
1>	CATEGORY/YEAR			1986	1987	1993		TOTAL
2>	BOMED VOLUME:							
3>	INSTANT:	F16		146.	146.	0.		SUM(B3:K3)
4>		USAF		44367.	44344.	0.		SUM(B4:K4)
5>		BOB		7227.	6407.	0.		SUM(B5:K5)
6>		COML		1944.	2708.	0.		SUM(B6:K6)
7>	SUBTOTAL:			SUM(C3:C6)	SUM(D3:D6)	SUM(J3:J6)		SUM(B7:K7)
8>	PROPOSED:	GOVT		0.	144.	630.		SUM(B8:K8)
9>		COML		0.	2448.	190.		SUM(B9:K9)
10>	SUBTOTAL:			SUM(C8:C9)	SUM(D8:D9)	SUM(J8:J9)		SUM(B10:K10)
11>	TOTAL:			C7+C10	D7+D10	J7+J10		SUM(B11:K11)
12>								
13>	ADJ #1 VOLUME:							
14>	INSTANT:	F16		C3	D3	J3		SUM(B14:K14)
15>		USAF		C4	D4	J4		SUM(B15:K15)
16>		BOB		C5	D5	J5		SUM(B16:K16)
17>		COML		C6	D6	J6		SUM(B17:K17)
18>	SUBTOTAL:			SUM(C14:C17)	SUM(D14:D17)	SUM(J14:J17)		SUM(B18:K18)
19>	PROPOSED:	GOVT		C8	D8	AVG(C22,F22)*(AVG(E19,F19)/AVG(C21,F21))		SUM(B19:K19)
20>		COML		C9	D9	AVG(C22,F22)*(AVG(C20,F20)/AVG(C21,F21))		SUM(B20:K20)
21>	SUBTOTAL:			SUM(C19:C20)	SUM(D19:D20)	SUM(J19:J20)		SUM(B21:K21)
22>	TOTAL:			C18+C21	D18+D21	AVG(C22,F22)		SUM(B22:K22)
23>								
24>	ADJ #2 VOLUME:							
25>	INSTANT:	F16		C14	D14	J14		SUM(B25:K25)
26>		USAF		C15	D15	J15		SUM(B26:K26)
27>		BOB		C16	D16	J16		SUM(B27:K27)
28>		COML		C17	D17	J17		SUM(B28:K28)
29>	SUBTOTAL:			SUM(C25:C28)	SUM(D25:D28)	SUM(J25:J28)		SUM(B29:K29)
30>	PROPOSED:	F16		C19*(L25/SUM(L25:L27))	D19*(L25/SUM	J19*(L25/SUM(L25:L27))		SUM(B30:K30)
31>		USAF		C19*(L26/SUM(L25:L27))	D19*(L26/SUM	J19*(L26/SUM(L25:L27))		SUM(B31:K31)
32>		BOB		C19*(L27/SUM(L25:L27))	D19*(L27/SUM	J19*(L27/SUM(L25:L27))		SUM(B32:K32)
33>		COML		C20	D20	J20		SUM(B33:K33)
34>	SUBTOTAL:			SUM(C30:C33)	SUM(D30:D33)	SUM(J30:J33)		SUM(B34:K34)
35>	TOTAL:			C29+C34	D29+D34	J29+J34		SUM(B35:K35)
36>								
37>	APPORT FACTORS:							
38>	INSTANT:	F16		C25/C$35	D25/C$35	J25/C$35		
39>		USAF		C26/C$35	D26/C$35	J26/C$35		
40>		BOB		C27/C$35	D27/C$35	J27/C$35		
41>		COML		C28/C$35	D28/C$35	J28/C$35		
42>	PROPOSED:	F16		C30/C$35	D30/C$35	J30/C$35		
43>		USAF		C31/C$35	D31/C$35	J31/C$35		
44>		BOB		C32/C$35	D32/C$35	J32/C$35		
45>		COML		C33/C$35	D33/C$35	J33/C$35		
46>	TOTAL:			SUM(C38:C45)	SUM(D38:D45)	SUM(J38:J45)		
47>								
48>	AS IS:TO BE:VOL			96.9	31.0	(12.-I48)/12.	1.-J48	
49>								
50>	INSTANT:	F16		(C38*C40*E48/60.)*J48	D38*C40*E48/	K48*J38*C40*E48/60.		SUM(B50:K50)
51>		USAF		(C39*C40*E48/60.)*J48	D39*C40*E48/	K48*J39*C40*E48/60.		SUM(B51:K51)
52>		BOB		(C40*C40*E48/60.)*J48	D40*C40*E48/	K48*J40*C40*E48/60.		SUM(B52:K52)
53>		COML		(C41*C40*E48/60.)*J48	D41*C40*E48/	K48*J41*C40*E48/60.		SUM(B53:K53)
54>	SUBTOTAL:			SUM(C50:C53)	SUM(D50:D53)	SUM(J50:J53)		SUM(B54:K54)
55>	PROPOSED:	F16		(C42*C40*E48/60.)*J48	D42*C40*E48/	K48*J42*C40*E48/60.		SUM(B55:K55)
56>		USAF		(C43*C40*E48/60.)*J48	D43*C40*E48/	K48*J43*C40*E48/60.		SUM(B56:K56)
57>		BOB		(C44*C40*E48/60.)*J48	D44*C40*E48/	K48*J44*C40*E48/60.		SUM(B57:K57)
58>		COML		(C45*C40*E48/60.)*J48	D45*C40*E48/	K48*J45*C40*E48/60.		SUM(B58:K58)
59>	SUBTOTAL:			SUM(C55:C58)	SUM(D55:D58)	SUM(J55:J58)		SUM(B59:K59)
60>	AS IS TOTAL:			C54+C59	D54+D59	J54+J59		SUM(B60:K60)
61>								
62>	INSTANT:	F16		(C38*D48*E48/60.)*J48	D38*D48*E48/	K48*J38*D48*E48/60.		SUM(B62:K62)
63>		USAF		(C39*D48*E48/60.)*J48	D39*D48*E48/	K48*J39*D48*E48/60.		SUM(B63:K63)
64>		BOB		(C40*D48*E48/60.)*J48	D40*D48*E48/	K48*J40*D48*E48/60.		SUM(B64:K64)
65>		COML		(C41*D48*E48/60.)*J48	D41*D48*E48/	K48*J41*D48*E48/60.		SUM(B65:K65)
66>	SUBTOTAL:			SUM(C62:C65)	SUM(D62:D65)	SUM(J62:J65)		SUM(B66:K66)
67>	PROPOSED:	F16		(C42*D48*E48/60.)*J48	D42*D48*E48/	K48*J42*D48*E48/60.		SUM(B67:K67)
68>		USAF		(C43*D48*E48/60.)*J48	D43*D48*E48/	K48*J43*D48*E48/60.		SUM(B68:K68)
69>		BOB		(C44*D48*E48/60.)*J48	D44*D48*E48/	K48*J44*D48*E48/60.		SUM(B69:K69)
70>		COML		(C45*D48*E48/60.)*J48	D45*D48*E48/	K48*J45*D48*E48/60.		SUM(B70:K70)
71>	SUBTOTAL:			SUM(C67:C70)	SUM(D67:D70)	SUM(J67:J70)		SUM(B71:K71)
72>	TO BE TOTAL:			C66+C71	D66+D71	J66+J71		SUM(B72:K72)
73>								
74>	INSTANT:	F16		C50-C62	D50-D62	J50-J62		SUM(B74:K74)
75>		USAF		C51-C63	D51-D63	J51-J63		SUM(B75:K75)
76>		BOB		C52-C64	D52-D64	J52-J64		SUM(B76:K76)
77>		COML		C53-C65	D53-D65	J53-J65		SUM(B77:K77)
78>	SUBTOTAL:			SUM(C74:C77)	SUM(D74:D77)	SUM(J74:J77)		SUM(B78:K78)
79>	PROPOSED:	F16		C55-C67	D55-D67	J55-J67		SUM(B79:K79)
80>		USAF		C56-C68	D56-D68	J56-J68		SUM(B80:K80)
81>		BOB		C57-C69	D57-D69	J57-J69		SUM(B81:K81)
82>		COML		C58-C70	D58-D70	J58-J70		SUM(B82:K82)
83>	SUBTOTAL:			SUM(C79:C82)	SUM(D79:D82)	SUM(J79:J82)		SUM(B83:K83)
84>	DELTA TOTAL:			C78+C83	D78+D83	J78+J83		SUM(B84:K84)

C3 thi
C8 thr alize Savings
C14 t alize Savings
listributed over
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TO-BE Total
C48 xuted over
D48 ;
E48

VOLUME II

SUPPORTING INFORMATION

(Page 2 thru 16)

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GENERAL DYNAMICS / FORT WORTH DIVISION          TRACOR, INC        FEBRUARY 6, 1987
DISCOUNTED CASH FLOW MODEL                      CAPS IMPROVEMENT PROJECT
INDUSTRIAL TECHNOLOGY MODERNIZATION PROGRAM     PHASE 3 PROPOSAL
                                                (LOTUS FILE C:\123REL2\TRACAPS.WK1)    MACROS FIXED!!!
//ITMDCF////ITMDCF////ITMDCF////ITMDCF////ITMDCF////ITMDCF////ITMDCF////ITMDCF////ITMDCF////ITMDCF////ITMDCF////ITMDCF////ITMDCF////ITMDCF////ITMDCF//
{GOTO}COSTSUM~/X@\A {GOTO}INVOHREC~/X@\C        {GOTO}DOD_FUND~/X@\S
{GOTO}SAV_SELL~/X@\B{GOTO}NET_INC~/X@\E         {GOTO}DOD_C_FLO~/X@\T
{GOTO}F16INST~/X@\W {GOTO}CASH_FLO~/X@\F        {GOTO}INV_PSRREC~/X@\D
{GOTO}F16FO~/X@\X   {GOTO}A12~{GOTO}F17~/X@\O
{GOTO}DTDODINS~/X@\Y{GOTO}INPUT~{GOTO}INPUT1~/X@\I
{GOTO}DTDODFO~/X@\Z {GOTO}PSR_IRR~{GOTO}PSR_IRR1~/X@\Q
```

THIS IS A DISCOUNTED CASH FLOW MODEL TO AID IN DETERMINING THE AMOUNT OF PSR REQUIRED FOR AN ADEQUATE IRR TO THE SUBCONTRACTOR. YOU MAY ACCESS THE SCHEDULES BY DEPRESSING THE ALT KEY AND THE DESIRED SCHEDULE LETTER. NOTE: SCHEDULES A1,A2,A3, AND A4 ARE ADDRESSED AS ALT W,X,Y, AND Z RESPECTIVELY. BEGIN BY ENTERING THE FIRST YEAR IN WHICH DATA WILL BE INPUTTED.---> 1984 <--- THEN DEPRESS THE F9 KEY. THIS KEY IS USED ANYTIME YOU WISH TO ACTIVATE THE SPREADSHEET'S CALCULATE MODE.

NOTE: WE RECOMMEND YOU WRITE PROTECT THIS SPREADSHEET AND THEN SAVE THE PROGRAM FILES YOU CREATE UNDER A UNIQUE NAME ON ANOTHER DISKETTE. GOOD LUCK. CALL THE ITM PROGRAM OFFICE IF YOU HAVE QUESTIONS OR COMMENTS. THANK YOU.

RATES AND HOURS BASED ON BID PKG'S DATED

THRU JANUARY 28, 1987

** AS SUBMITTED IN PROPOSAL. **

*** UNAUDITED ***

GENERAL SPREADSHEET INPUTS SUCH AS HOURLY RATES, OVERHEADS, AND DOD SHARE OF SAVINGS MAY BE MADE BY DEPRESSING ALT I. CELLS WHERE INPUTS ARE REQUIRED ARE LABELED WITH ---> AND/OR <--- DERIVED CELLS ARE DESIGNATED BY *** AND/OR ***. THIS DOES NOT APPLY TO INPUTS TO SCHEDULES SUCH AS, A1 THROUGH A4 AND C.

THE FIRST YEAR IN WHICH INPUTS WILL BE MADE IS*** 1984 ***

		LATEST RATES	1984	1985	1986	1987	1988
CAPITAL EQUIPMENT COSTS?--->	214492 <----	MTL SAV->	0.0000	0.0000	0.0000	0.0000	0.0000
		MFG SAV->	0.0000	0.0000	1.2777	1.2370	1.2680
DOD SHARE TOTAL BUSINESS?***	0.80 ***	ENG SAV->	0.0000	0.0000	0.0000	0.0000	0.0000
		G&A SAV->	0.0000	0.0000	0.1882	0.1590	0.1620
DOD SHARE OF SAVINGS ****	1.00 ***	FRINGE-->	0.3200	0.2470	0.2630	0.2630	0.2630
		PROFIT-->	0.1500	0.1500	0.1500	0.1500	0.1500
		COM----->	0.0000	0.0000	0.0515	0.0384	0.0326
		PLANT OH>				0.0750	0.0790
		MTL INV->	0.1236	0.1124	0.1272	0.0000	0.0000
		MFG INV->	1.6194	1.5764	1.2826	0.0000	0.0000
		ENG INV->	1.2428	1.2936	1.3409	0.0000	0.0000

HOURLY RATES WITH PSI

JOB CLASSIFICATION YEAR	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
MFG ENG & TEST ENG, M02	0.00	0.00	17.21	17.20	18.23	19.33	20.49	21.71	23.02	24.40
MFG ASSY (INST SHEET), M07	0.00	0.00	6.44	7.07	7.49	7.94	8.42	8.93	9.46	10.03
MFG ASSY (COMP INS GEN), M07	0.00	0.00	6.67	7.07	7.49	7.94	8.42	8.93	9.46	10.03
MFG TEST TECH PWB ASSY (TEST), M08	0.00	0.00	10.27	10.98	11.64	12.34	13.08	13.86	14.69	15.58
MFG TEST TECH PWB ASSY (REPAIR), M08	0.00	0.00	10.50	10.98	11.64	12.34	13.08	13.86	14.69	15.58

ENTER DOD SHARE--->>	1.00000 <<---	RESULTING DOD NPV***	110	NPV TO DOD WITH A***	63634	***SHARE YIELDS***	110	***
DOD DISCOUNT FACTOR>	0.06 <<---	RESULTING VND IRR***	0.3543	VENDOR IRR WITH A***	283664	***SHARE YIELDS***	0.3543	***
VENDOR DISC FACTOR>>	0.20 <<---	RESULTING VND NPV***	39791	VENDOR NPV WITH A***	0.20	***DISCOUNT FACTOR*	39791	***

YEAR	VENDOR CAPITAL	PSR
1984	-114238	0
1985	3257	0
1986	79399	109261
1987	119869	146623
1988	48180	27780
1989	15854	0
1990	14098	0
1991	1572	0
1992	0	0
1993	0	0
TOTAL	167990	283664

YEAR	DOD SAVINGS
1984	-72934
1985	-25371
1986	-40765
1987	-24979
1988	30987
1989	8377
1990	39895
1991	66353
1992	73333
1993	8740
TOTAL	63634

INSTANT F-16 SAVINGS	693
INSTANT OTHER DOD SAVINGS	282971
TOTAL INSTANT SAVINGS	283664
CONTRACTOR PSR	283664

CONTRACTOR PERFORMANCE INCENTIVE ******* 0 *******

****

SCHEDULE A1 FORECASTED INSTANT F-16 SAVINGS
-ALT W-

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
1. MATERIALS	0	0	0	0	0	0	0	0	0	0	0
2. MFG ENG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3. $HOURLY RATE	0.00	0.00	17.21	17.20	18.23	19.33	20.49	21.71	23.02	24.40	
4. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
5. MFG ASSY INST SHEET	0.0	0.0	13.9	15.8	0.0	0.0	0.0	0.0	0.0	0.0	29.6
6. $HOURLY RATE	0.00	0.00	6.44	7.07	7.49	7.94	8.42	8.93	9.46	10.03	
7. SUBTOTAL	0	0	89	111	0	0	0	0	0	0	201
8. MFG ASSY COMP INS GEN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9. $HOURLY RATE	0.00	0.00	6.67	7.07	7.49	7.94	8.42	8.93	9.46	10.03	
10. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
11. TEST ENG	0.0	0.0	0.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.6
12. $HOURLY RATE	0.00	0.00	17.21	17.20	18.23	19.33	20.49	21.71	23.02	24.40	
13. SUBTOTAL	0	0	2	9	0	0	0	0	0	0	10
14. TEST TECH PWB ASSY TEST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15. $HOURLY RATE	0.00	0.00	10.27	10.98	11.64	12.34	13.08	13.86	14.69	15.58	
16. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
17. TEST TECH PWB ASSY REPAIR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18. $HOURLY RATE	0.00	0.00	10.50	10.98	11.64	12.34	13.08	13.86	14.69	15.58	
19. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
20. OTHER (SPECIFY)	0	0	0	0	0	0	0	0	0	0	0
21. TOTAL DIRECT	0	0	91	120	0	0	0	0	0	0	211
22. MTL SAV (ALLOWABLE OH)	0	0	0	0	0	0	0	0	0	0	0
23. MFG SAV (ALLOWABLE OH)	0	0	116	148	0	0	0	0	0	0	265
24. PLANT OH (ALLOWABLE OH)	0	0	0	20	0	0	0	0	0	0	20
25. G&A SAV (ALLOWABLE OH)	0	0	39	46	0	0	0	0	0	0	85
26. TOTAL INDIRECT	0	0	155	214	0	0	0	0	0	0	370
27. SAVINGS THRU G&A	0	0	246	334	0	0	0	0	0	0	581

SCHEDULE A2 FORECASTED F/O F-16 SAVINGS
-ALT X-

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
1. MATERIALS	0	0	0	0	0	0	0	0	0	0	0
2. MFG ENG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3. #HOURLY RATE	0.00	0.00	17.21	17.20	18.23	19.33	20.49	21.71	23.02	24.40	
4. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
5. MFG ASSY INST SHEET	0.0	0.0	0.0	0.0	4.8	3.0	5.1	5.1	5.1	0.0	23.2
6. #HOURLY RATE	0.00	0.00	6.44	7.07	7.49	7.94	8.42	8.93	9.46	10.03	
7. SUBTOTAL	0	0	0	0	36	24	43	46	48	0	197
8. MFG ASSY COMP INS GEN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9. #HOURLY RATE	0.00	0.00	6.67	7.07	7.49	7.94	8.42	8.93	9.46	10.03	
10. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
11. TEST ENG	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.6
12. #HOURLY RATE	0.00	0.00	17.21	17.20	18.23	19.33	20.49	21.71	23.02	24.40	
13. SUBTOTAL	0	0	0	0	2	2	2	2	2	2	13
14. TEST TECH PWB ASSY TEST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15. #HOURLY RATE	0.00	0.00	10.27	10.98	11.64	12.34	13.08	13.86	14.69	15.58	
16. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
17. TEST TECH PWB ASSY REPAIR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18. #HOURLY RATE	0.00	0.00	10.50	10.98	11.64	12.34	13.08	13.86	14.69	15.58	
19. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
20. OTHER (SPECIFY)	0	0	0	0	0	0	0	0	0	0	0
21. TOTAL DIRECT	0	0	0	0	38	26	45	48	51	2	210
22. MTL SAV (ALLOWABLE OH)	0	0	0	0	0	0	0	0	0	0	0
23. MFG SAV (ALLOWABLE OH)	0	0	0	0	48	33	57	61	64	3	266
24. PLANT OH (ALLOWABLE OH)	0	0	0	0	7	5	8	9	9	0	38
25. G&A SAV (ALLOWABLE OH)	0	0	0	0	15	10	18	19	20	1	83
26. TOTAL INDIRECT	0	0	0	0	70	48	83	88	93	4	387
27. SAVINGS THRU G&A	0	0	0	0	108	73	128	136	144	7	597

SCHEDULE A3 FORECASTED INSTANT OTHER DOD SAVINGS
-ALT Y-

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
1. MATERIALS	0	0	0	0	0	0	0	0	0	0	0
2. MFG ENG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3. *HOURLY RATE	0.00	0.00	17.21	17.20	18.23	19.33	20.49	21.71	23.02	24.40	
4. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
5. MFG ASSY INST SHEET	0.0	0.0	4823.3	4959.6	839.0	0.0	0.0	0.0	0.0	0.0	10621.9
6. *HOURLY RATE	0.00	0.00	6.44	7.07	7.49	7.94	8.42	8.93	9.46	10.03	
7. SUBTOTAL	0	0	31062	35065	6288	0	0	0	0	0	72414
8. MFG ASSY COMP INS GEN	0.0	0.0	1.5	9.3	1.5	0.0	0.0	0.0	0.0	0.0	12.3
9. *HOURLY RATE	0.00	0.00	6.67	7.07	7.49	7.94	8.42	8.93	9.46	10.03	
10. SUBTOTAL	0	0	10	66	11	0	0	0	0	0	87
11. TEST ENG	0.0	0.0	23.0	142.3	24.1	0.0	0.0	0.0	0.0	0.0	189.4
12. *HOURLY RATE	0.00	0.00	17.21	17.20	18.23	19.33	20.49	21.71	23.02	24.40	
13. SUBTOTAL	0	0	396	2448	439	0	0	0	0	0	3283
14. TEST TECH PWB ASSY TEST	0.0	0.0	177.2	395.8	90.2	0.0	0.0	0.0	0.0	0.0	663.2
15. *HOURLY RATE	0.00	0.00	10.27	10.98	11.64	12.34	13.08	13.86	14.69	15.58	
16. SUBTOTAL	0	0	1820	4346	1050	0	0	0	0	0	7216
17. TEST TECH PWB ASSY REPAIR	0.0	0.0	21.2	202.5	40.6	0.0	0.0	0.0	0.0	0.0	264.3
18. *HOURLY RATE	0.00	0.00	10.50	10.98	11.64	12.34	13.08	13.86	14.69	15.58	
19. SUBTOTAL	0	0	223	2223	473	0	0	0	0	0	2919
20. OTHER (SPECIFY)	0	0	0	0	0	0	0	0	0	0	0
21. TOTAL DIRECT	0	0	33510	44147	8261	0	0	0	0	0	85918
22. MTL SAV (ALLOWABLE OH)	0	0	0	0	0	0	0	0	0	0	0
23. MFG SAV (ALLOWABLE OH)	0	0	42816	54610	10475	0	0	0	0	0	107901
24. PLANT OH (ALLOWABLE OH)	0	0	0	7407	1480	0	0	0	0	0	8887
25. G&A SAV (ALLOWABLE OH)	0	0	14365	16880	3275	0	0	0	0	0	34520
26. TOTAL INDIRECT	0	0	57181	78897	15230	0	0	0	0	0	151307
27. SAVINGS THRU G&A	0	0	90691	123044	23490	0	0	0	0	0	237226

SCHEDULE A4 FORECASTED F/O OTHER DOD SAVINGS
-ALT 2-

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
1. MATERIALS	0	0	0	0	0	0	0	0	0	0	0
2. MFG ENG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3. #HOURLY RATE	0.00	0.00	17.21	17.20	18.23	19.33	20.49	21.71	23.02	24.40	
4. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
5. MFG ASSY INST SHEET	0.0	0.0	0.0	15.5	1727.6	1075.6	1823.2	1823.2	1823.2	0.0	8288.2
6. #HOURLY RATE	0.00	0.00	6.44	7.07	7.49	7.94	8.42	8.93	9.46	10.03	
7. SUBTOTAL	0	0	0	110	12947	8545	15352	16273	17249	0	70475
8. MFG ASSY COMP INS GEN	0.0	0.0	0.0	0.0	3.2	2.1	3.4	3.4	3.4	2.8	18.3
9. #HOURLY RATE	0.00	0.00	6.67	7.07	7.49	7.94	8.42	8.93	9.46	10.03	
10. SUBTOTAL	0	0	0	0	24	17	29	30	32	28	160
11. TEST ENG	0.0	0.0	0.0	0.5	49.6	30.9	52.3	52.3	52.3	43.6	281.5
12. #HOURLY RATE	0.00	0.00	17.21	17.20	18.23	19.33	20.49	21.71	23.02	24.40	
13. SUBTOTAL	0	0	0	9	904	597	1071	1136	1204	1064	5985
14. TEST TECH PWB ASSY TEST	0.0	0.0	0.0	0.0	168.7	45.8	152.4	152.4	152.4	38.1	709.8
15. #HOURLY RATE	0.00	0.00	10.27	10.98	11.64	12.34	13.08	13.86	14.69	15.58	
16. SUBTOTAL	0	0	0	0	1963	565	1993	2113	2239	593	9467
17. TEST TECH PWB ASSY REPAIR	0.0	0.0	0.0	0.0	75.8	23.2	70.2	70.2	70.2	58.5	368.1
18. #HOURLY RATE	0.00	0.00	10.50	10.98	11.64	12.34	13.08	13.86	14.69	15.58	
19. SUBTOTAL	0	0	0	0	882	286	918	973	1031	911	5002
20. OTHER (SPECIFY)	0	0	0	0	0	0	0	0	0	0	0
21. TOTAL DIRECT	0	0	0	118	16721	10010	19363	20525	21756	2596	91089
22. MTL SAV (ALLOWABLE OH)	0	0	0	0	0	0	0	0	0	0	0
23. MFG SAV (ALLOWABLE OH)	0	0	0	147	21202	12692	24552	26025	27587	3292	115497
24. PLANT OH (ALLOWABLE OH)	0	0	0	20	2996	1793	3469	3677	3898	465	16319
25. G&A SAV (ALLOWABLE OH)	0	0	0	45	6629	3968	7676	8137	8625	1029	36110
26. TOTAL INDIRECT	0	0	0	212	30827	18454	35698	37839	40110	4787	167926
27. SAVINGS THRU G&A	0	0	0	330	47548	28464	55060	58364	61866	7383	259015

SCHEDULE A BY ELEMENT SAVINGS SUMMARY TO COST

-ALT A-

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
1. MATERIALS	0	0	0	0	0	0	0	0	0	0	0
2. MFG ENG	0	0	0	0	0	0	0	0	0	0	0
3. *HOURLY RATE	0.00	0.00	17.21	17.20	18.23	19.33	20.49	21.71	23.02	24.40	
4. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
5. MFG ASSY INST SHEET	0	0	4837	4991	2571	1079	1828	1828	1828	0	18963
6. *HOURLY RATE	0.00	0.00	6.44	7.07	7.49	7.94	8.42	8.93	9.46	10.03	
7. SUBTOTAL	0	0	31151	35286	19271	8568	15395	16319	17298	0	143287
8. MFG ASSY COMP INS GEN	0	0	2	9	5	2	3	3	3	3	31
9. *HOURLY RATE	0.00	0.00	6.67	7.07	7.49	7.94	8.42	8.93	9.46	10.03	
10. SUBTOTAL	0	0	10	66	35	17	29	30	32	28	247
11. TEST ENG	0	0	23	143	74	31	52	52	52	44	472
12. *HOURLY RATE	0.00	0.00	17.21	17.20	18.23	19.33	20.49	21.71	23.02	24.40	
13. SUBTOTAL	0	0	398	2465	1346	599	1073	1138	1206	1066	9291
14. TEST TECH PWB ASSY TEST	0	0	177	396	259	46	152	152	152	38	1373
15. *HOURLY RATE	0.00	0.00	10.27	10.98	11.64	12.34	13.08	13.86	14.69	15.58	
16. SUBTOTAL	0	0	1820	4346	3013	565	1993	2113	2239	593	16682
17. TEST TECH PWB ASSY REPAIR	0	0	21	203	116	23	70	70	70	59	632
18. *HOURLY RATE	0.00	0.00	10.50	10.98	11.64	12.34	13.08	13.86	14.69	15.58	
19. SUBTOTAL	0	0	223	2223	1355	286	918	973	1031	911	7921
20. OTHER (SPECIFY)	0	0	0	0	0	0	0	0	0	0	0
21. TOTAL DIRECT	0	0	33601	44386	25020	10036	19408	20572	21807	2599	177428
22. MTL SAV (ALLOWABLE OH)	0	0	0	0	0	0	0	0	0	0	0
23. MFG SAV (ALLOWABLE OH)	0	0	42932	54905	31725	12725	24609	26086	27651	3295	223929
24. PLANT OH (ALLOWABLE OH)	0	0	0	7447	4483	1798	3477	3686	3907	466	25264
25. G&A SAV (ALLOWABLE OH)	0	0	14404	16971	9919	3979	7694	8156	8645	1030	70798
26. TOTAL INDIRECT	0	0	57336	79323	46127	18502	35781	37928	40203	4791	319990
27. SAVINGS THRU G&A	0	0	90937	123709	71146	28537	55189	58500	62010	7390	497418

SCHEDULE B TOTAL SAVINGS BY PROGRAM TO SELL

-ALT B-

		1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
SUBCONTRACTOR SHARE												
1. INSTANT F-16		0	0	296	397	0	0	0	0	0	0	693
2. F/O F-16		0	0	0	0	0	0	0	0	0	0	0
3. INSTANT OTHER DOD		0	0	108965	146226	27780	0	0	0	0	0	282971
4. F/O OTHER DOD		0	0	0	0	0	0	0	0	0	0	0
5. SUBTOTAL		0	0	109261	146623	27780	0	0	0	0	0	283664
DOD SHARE												
6. INSTANT F-16		0	0	0	0	0	0	0	0	0	0	0
7. F/O F-16		0	0	0	0	128	87	152	161	170	8	706
8. INSTANT OTHER DOD		0	0	0	0	0	0	0	0	0	0	0
9. F/O OTHER DOD		0	0	0	392	56230	33661	65114	69021	73163	8731	306314
10. SUBTOTAL		0	0	0	392	56358	33748	65266	69182	73333	8740	307019
TOTAL SAVINGS												
11. INSTANT F-16	(SCH A1)	0	0	296	397	0	0	0	0	0	0	693
12. F/O F-16	(SCH A2)	0	0	0	0	128	87	152	161	170	8	706
13. INSTANT OTHER DOD	(SCH A3)	0	0	108965	146226	27780	0	0	0	0	0	282971
14. F/O OTHER DOD	(SCH A4)	0	0	0	392	56230	33661	65114	69021	73163	8731	306314
15. TOTAL		0	0	109261	147016	84138	33748	65266	69182	73333	8740	590683

SCHEDULE C FORECASTED EXPENSES/INVESTMENT (DOD RECOVERABLE)
-ALT C-

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
1. MATERIALS	0	0	0								0
2.	0.0	0.0	0.0								
3. *HOURLY RATE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
4. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
5.	0.0										
6. *HOURLY RATE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
7. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
8.	0.0										
9. *HOURLY RATE	0.00										0.0
10. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
11. OTHER: MAINT. AGREEMENTS & FIR'S *.8	9970										9970
12. TOTAL DIRECT	9970	0	0	0	0	0	0	0	0	0	9970
13. FRINGE (OH ON LABOR ONLY)	0	0	0	0	0	0	0	0	0	0	0
14. TOTAL INDIRECT	0	0	0	0	0	0	0	0	0	0	0
15. DEPRECIATION (CAS409)	19602	22062	22062	22062	22062	22062	22062	2460	0	0	154435
16. TOTAL	29572	22062	22062	22062	22062	22062	22062	2460	0	0	164405

SCHEDULE D FORECASTED EXPENSES/INVESTMENT (PSR RECOVERABLE)
-ALT D-

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
1. MATERIALS	0	0	0	0	0	0	0	0	0	0	0
2.	0	0	0	0	0	0	0	0	0	0	0.0
3. *HOURLY RATE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
4. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
5.	0	0.0	0	0	0	0	0	0	0	0	0.0
6. *HOURLY RATE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
7. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
8.		0.0	0.0								0.0
9. *HOURLY RATE		0.00	0.00								
10. SUBTOTAL	0	0	0	0	0	0	0	0	0	0	0
11.	0	0	0								0
12. PART OF TRACOR CAT II OVERRUN * 80%	0	16913	16913								33826
13. TOTAL DIRECT	0	16913	16913	0	0	0	0	0	0	0	33826
14. FRINGE (OH ON LABOR ONLY)	0	0	0	0	0	0	0	0	0	0	0
15. TOTAL INDIRECT	0	0	0	0	0	0	0	0	0	0	0
16. DEPRECIATION	0	0	0	0	0	0	0	0	0	0	0
17. TOTAL	0	16913	16913	0	0	0	0	0	0	0	33826

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SCHEDULE E FORECASTED SUBCONTRACTOR NET INCOME
-ALT E-

		1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
1. GROSS SAVINGS	(SCH B)	0	0	109261	147016	84138	33748	65266	69182	73333	8740	590683
2. LESS EXPENSES AT SELL	(SCH C)	34008	25371	25371	25371	25371	25371	25371	2829	0	0	189065
3. SAVINGS AVAILABLE		-34008	-25371	83889	121644	58766	8377	39895	66353	73333	8740	401618
4. LESS: DOD SHARE		-34008	-25371	-25371	-24979	30987	8377	39895	66353	73333	8740	117954
5. PROD SAVINGS RWD		0	0	109261	146623	27780	0	0	0	0	0	283664
6. LESS: EXPENSES	(SCH D)	0	16913	16913	0	0	0	0	0	0	0	33826
7. ADD: PROFIT ON SCH C		4436	3309	3309	3309	3309	3309	3309	369	0	0	24661
8. OTHER (SPECIFY +/-)		0	0	0	0	0	0	0	0	0	0	0
9. CONTRACTOR TAXABLE INCOME		4436	-13604	95657	149933	31089	3309	3309	369	0	0	274499
10. LESS: CORP TAX? 0.46		2040	-6258	44002	57724	10570	1125	1125	125	0	0	126269
11. ADD: INVEST TAX CREDIT		15246	1914	0								17159
CAPITAL COSTS? 214492												
%DOD BUSINESS? 0.80												
12. SUBCONTRACTOR NET INCOME		17641	-5432	51655	92209	20519	2184	2184	244	0	0	165389
13. DEPRECIATION (TAX)		21725	34591	34415	34233	34233	3818	0	0	0	0	163014
14. DEFERRED TAXES		977	5763	5682	5599	5599	-8392	-10149	-1132	0	0	3947

SCHEDULE F SCHEDULE OF FORECASTED AFTER TAX CASH FLOW
-ALT F-

		1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
1. ADD: NET INCOME	(SCH E)	17641	-5432	51655	92209	20519	2184	2184	244	0	0	165389
2. DEPRECIATION (CAS 409)	(SCH C/D)	19602	22062	22062	22062	22062	22062	22062	2460	0	0	154435
3. DEFERRED TAXES	(SCH E)	977	5763	5682	5599	5599	-8392	-10149	-1132	0	0	3947
4. NBV OF DISPOSABLE F/A												0
5. OTHER (SPECIFY)												0
6. LESS: CAPITAL INVESTMENT		152458	19136	0								171594
7. OTHER (SPECIFY)												0
		------	------	------	------	------	------	------	------	------	------	------
8. AFTER TAX CASH FLOW		-114238	3257	79399	119869	48180	15854	14098	1572	0	0	167990
9. CUMULATIVE ATC FLOW		-114238	-110982	-31582	88287	136466	152320	166418	167990	167990	167990	167990

10. WITH A DISCOUNT FACTOR *** 0.2000 ***NPV IS* 39791 **

11. SUBCONTRACTOR IRR 0.3543
GUESS? 0.40

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SUPPORT FILE 1 SCHEDULE OF FORECASTED DOD PHASE 1&2 FUNDING

-ALT S-

YEAR	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
1. PHASE 1 FUNDING	38926										38926
2. PHASE 2 FUNDING	0	0	15394								15394
3. TOTAL DOD FUNDING	38926	0	15394	0	0	0	0	0	0	0	54320
ADJUST PREVIOUS FUNDING TO 1984											

SUPPORT FILE 2 DOD BUSINESS SHARE COMPUTATION

-ALT S-

YEAR	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
1. NUMBER OF DOD UNITS	0	0	0	0	0	0	0	0	0	0	0
2. TOTAL NUMBER OF UNITS	0	0	0	0	0	0	0	0	0	0	0
3. DOD BUSINESS SHARE (#1/#2)	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	ERR	0.800

SUPPORT FILE 3 SUMMARY OF DOD CASH FLOWS

-ALT T-

YEAR	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	TOTAL
1. SAVINGS AVAILABLE TO DOD (SCHED E)	-34008	-25371	83889	121644	58766	8377	39895	66353	73333	8740	401618
2. DOD COMPONENT FUNDING (FILE 1)	38926	0	15394	0	0	0	0	0	0	0	54320
3. DOD PROGRAM BENEFIT (W/O INCENTIVE)	-72934	-25371	68495	121644	58766	8377	39895	66353	73333	8740	347298
4. NPV @> 0.06 (W/O INC)*228745.58											
5. DOD PROGRAM BENEFIT (WITH INCENTIVE)	-72934	-25371	-40765	-24979	30987	8377	39895	66353	73333	8740	63634
6. NPV @> 0.06 (W/ INC)** 110.01											

DEPRECIATION CALCS	AFTER DDD % BEFORE SALVAGE											
FINANCIAL (CAS 409)												
STRAIGHT LINE 7YRS., 10%												
ASSETS PURCHASED IN 1984	152458	19602	19602	19602	19602	19602	19602	19602				137212
ASSETS PURCHASED IN 1985	19136		2460	2460	2460	2460	2460	2460	2460			17222
ASSETS PURCHASED IN 1986				0	0	0	0	0	0	0		0
TOTAL DEPRECIATION		19602	22062	22062	22062	22062	22062	22062	2460	0	0	154435
BOOK VALUE (AFTER SALV. %)	154435	134833	112771	90709	68647	46585	24522	2460	0	0	0	
TAX												
DDB, 7 YRS., 10% SALV												
ASSETS PURCHASED IN 1984	152458	43559	31114	22224	15874	11339	8099	5002				137212
ASSETS PURCHASED IN 1985	19136		5467	3905	2790	1993	1423	1017	628			17222
ASSETS PURCHASED IN 1986				0	0	0	0	0	0	0		0
TOTAL DEPRECIATION		43559	36581	26130	18664	13331	9522	6019	628	0	0	154435
BOOK VALUE (AFTER SALV. %)	154435	110875	74294	48164	29500	16169	6647	628	0	0	0	
TAX												
ACRS, 5 YRS., 5% SALV												
ASSETS PURCHASED IN 1984	152458	21725	31864	30415	30415	30415						144835
ASSETS PURCHASED IN 1985	19136		2727	3999	3818	3818	3818					18179
ASSETS PURCHASED IN 1986												0
TOTAL DEPRECIATION		21725	34591	34415	34233	34233	3818	0	0	0	0	163014
BOOK VALUE (AFTER SALV. %)	163014	141289	106698	72284	38051	3818	0	0				

END OF PROPOSAL